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NATURE OF THE GLASS PHASE IN HEATED CLAY MATERIALS: II*

Effect of Rate of Heating on the Glass Phase and Physical Properties of Whiteware Bodies

By George R. Shelton and William W. Meyer

Abstract

The glass phase in the bodies studied was more sensitive to variations in heat treatment than were the physical properties. Increased rates of heating caused less glass and mullite formation, less quartz corrosion, more pores and blebs, and increased heterogeneity of the glassy matrix. Microstructure and physical properties indicated an optimum heating rate between 50° and 90° per hour. Soaking increased the amount of glass, more so after slow than after rapid heating. Soaking after rapid heating did not reduce the number of blebs. Soaking too long and at too high temperatures made blebs more numerous. A minimum soaking time of one hour seemed desirable. The optimum heating rate and minimum soaking time governed the shortest heating schedule productive of the best microstructure and physical properties.

I. Introduction

In reporting the effects of variation in firing on the physical properties of vitreous china bodies, Sortwell[1] stated that the heat treatment was the most variable factor in the manufacturing process. Geller and Creamer[2] found that the mechanical strength of bodies was influenced more by the method of firing than by variation in the feldspar. Klein[3] reported that the constitution and microstructure of porcelain bodies were dependent on the time and temperature of heating. Experiments were cited by Mellor[4] to prove that an extended time could do work which required a higher temperature when the time was abbreviated. The effects of time and temperature on the microstructure of porcelain were investigated by Peck.[5] The quantitative relations between these two factors were later studied by Norton and Hodgdon,[6] and the microstructure of the specimens was investigated by Norton.[7] The chief factor studied[7] was the length of time of soaking, inasmuch as only a single and very rapid rate of temperature rise was used. Watts[8] conducted some experiments on whiteware bodies heated at about 25° and 30° per hour, but no report was made of the petrographic examinations.

In previous investigations of the microstructure of whiteware, emphasis has been placed on the crystalline constituents, quartz and mullite. The combined amounts of these materials are usually less than that of the glassy portion which, although its importance has been recognized, has not received all of the consideration it merits.[9]

There is a lack of agreement concerning the effect of shortening the heat treatments of whiteware and of variations in heating rate. Satisfactory results were reported[10] from a schedule of 30 hours to cone 10, while a reduction to 18 hours to reach cone 10 was unsatisfactory. The work of Gould and Hedquist[11] indicates that dinnerware can be heated at rates up to 200°C per hour after reaching 1000°C. In this laboratory, a heating schedule of 180° per hour with a one-hour soaking

* Received May 4, 1938.

For Part I, see G. R. Shelton, "Nature of the Glass Phase in Heated Clay Materials: I, The Common Clays," *Jour. Amer. Ceram. Soc.*, **18** [10] 289–96 (1935).

[1] H. H. Sortwell, "Effect of Variation in Firing on Physical Properties of Vitreous China Bodies," *ibid.*, **6** [8] 915–36 (1923).

[2] R. F. Geller and A. S. Creamer, "Investigation of Feldspar and Its Effect in Pottery Bodies," *ibid.*, **14** [1] 30–71 (1931).

[3] (*a*) A. A. Klein, "Constitution and Microstructure of Porcelain," *Trans. Amer. Ceram. Soc.*, **18**, 377–423 (1916).

(*b*) A. A. Klein, "Time and Temperature of Burning as Factors Influencing Constitution and Microstructure of a Porcelain Body," *Jour. Amer. Ceram. Soc.*, **3**, 978–83 (1920).

[4] J. W. Mellor, "Can the Firing Temperature of a Body Be Determined from Microscopic Appearance," *Trans. Ceram. Soc.* [Eng.], **16**, 71–72 (1917).

[5] A. B. Peck, "Effect of Time and Temperature on Microstructure of Porcelain," *Jour. Amer. Ceram. Soc.*, **2** [3] 175–94 (1919).

[6] F. H. Norton and F. B. Hodgdon, "Influence of Time on Maturing Temperature of Whiteware Bodies: I," *ibid.*, **14** [3] 177–91 (1931).

[7] C. L. Norton, Jr., "Influence of Time on Maturing Temperature of Whiteware Bodies: II," *ibid.*, **14** [3] 192–206 (1931).

[8] A. S. Watts, "Data on Influence of Firing Time on Properties of Some Whiteware Bodies," *ibid.*, **19** [6] 175–76 (1936).

[9] (*a*) H. M. Kraner, "Importance of Glass Phase in Porcelain," *ibid.*, **12** [6] 383–89 (1929); also *Ind. Eng. Chem.*, **23**, 1098 (1931).

(*b*) G. W. Morey, "Glass: the Bond in Ceramics," *Jour. Amer. Ceram. Soc.*, **17** [6] 145–55 (1934).

[10] Colloquium on Whiteware, 1936, Ohio Clay Industrial Assn. Meeting.

[11] R. E. Gould and A. J. Hedquist, "VII, Experimental Electrical Firing of True Porcelain and China-Type Bodies Made from American Materials for Determination of Suitable Schedules," *Jour. Amer. Ceram. Soc.*, **20** [6] 207–14 (1937).

period has been used[12] in treating whiteware specimens.

A need for further work was indicated by this lack of agreement in heating rates and by insufficient emphasis on the glass phase in studying the microstructure of whiteware. This is a report of an investigation to determine and correlate the effects of various heat treatments on the glass phase and physical properties of vitreous and semivitreous feldspathic whiteware.

reground 10 hours in a laboratory ball mill. Microscopic estimation showed that the reground feldspar contained approximately half as many coarse particles (over 20μ) as the commercial feldspar. Body K contained North Carolina kaolin prepared by the Zettlitz process with approximately only 10% of the particles more than 10μ in diameter (microscopic estimation). Georgia kaolin contained approximately 20% of particles more than 10μ in diameter.

TABLE I

COMPOSITION OF RAW MATERIALS

	Raw Materials						
	Ky. ball clay No. 4 (%)	Tenn. ball clay No. 5 (%)	Fla. (ball) kaolin (%)	Ga. kaolin (%)	N.C. kaolin (%)	Maine feldspar (%)	Flint (%)
Ignition loss	14.7	13.6	13.7	13.7	14.2	0.3	
SiO_2	49.9	50.3	46.3	45.7	44.4	72.7	100
Al_2O_3	31.4	31.5	37.7	38.7	39.7	15.1	
Fe_2O_3	0.6	0.6	0.8	0.3	0.3	0.1	
TiO_2	1.5	1.3	0.5	1.4	*	0.1	
CaO	0.2	0.2	0.5	0.2	0.2	0.3	
MgO	0.3	0.3	*	*	0.3	*	
K_2O	1.2	2.0	0.2	0.0	0.7	8.3	
Na_2O	0.2	0.3	0.0	*	0.1	3.1	
RO	1.9	2.8	0.7	0.2	1.3	11.7	
RO_2	51.4	51.6	46.8	47.1	44.4	72.8	100
R_2O_3	32.0	32.1	38.5	39.0	40.0	15.2	

* Trace.

TABLE II

BODY COMPOSITIONS

	Raw Material Content							Ignited body (%)		
Body No.	Ky. ball clay No. 4 (%)	Tenn. ball clay No. 5 (%)	Fla. (ball) kaolin (%)	Ga. kaolin (%)	N.C. kaolin (%)	Maine feldspar (%)	Flint (%)	RO	RO_2	R_2O_3
AF* } A }	10.0	10.0	5.0	20.0		36.0	19.0	5.1	71.8	23.1
BF* } B }	10.0	10.0	5.0	20.0		15.0	40.0	2.5	77.8	19.7
A3	10.3	10.3	5.1	19.9		35.2	19.2	5.0	71.8	23.2
K	9.3	9.3	4.7		22.1	33.4	21.2	5.0	71.8	23.2

* Feldspar reground 10 hr. in laboratory ball mill.

II. Preparation of Specimens and Test Methods

The body materials used were Kentucky and Tennessee ball clays; Florida, Georgia, and North Carolina kaolins; Maine feldspar; and flint. The compositions are given in Table I. Three vitreous bodies and one semivitreous body (Table II) were prepared and used in the tests. One vitreous body, AF, and one semivitreous body, BF, contained feldspar which had been

The body slip, which had a specific gravity of about 1.90, was deflocculated with sodium gallate, mixed in an electric churn, and de-aired. The small size of the churn made it necessary to mix three batches of slip in the case of bodies A, B, and A3 (see footnotes to Table III). Specimens, approximately 1 by 1 by 8 cm., were cast and dried, and the faces of the bars were sanded to decrease the possibility of any skin effect. After determining the weights and volumes in the dry condition, the specimens were heated in an electric furnace. Heat treatments were calculated by

[12] W. W. Meyer and T. A. Klinefelter, "Substitution of Domestic for Imported Clays in Whiteware Bodies," *Jour. Research Nat. Bur. Stand.*, **19** [1] 65–79 (1937); R. P. 1011; *Ceram. Abs.*, **16** [9] 280 (1937).

the formula derived by Meyer.[13] Approximate values of A_Σ,* corresponding to the vitrification ranges of the bodies, were taken from his graph correlating A_Σ and RO content for the vitrification of feldspathic whiteware bodies. The approximate range for bodies A and AF is A_Σ = 0.17 to 1.7 and, for bodies A3 and K, A_Σ = 0.19 to 1.9.

* A_Σ represents the total amount of reaction in a body, relative to that which would take place during one hour at a temperature of 1280°C. It is calculated from the empirical equation,

$$A_\Sigma = \frac{0.0166}{r} \times 10^{0.0251\,(t-1150)} - 0.001h + h_s(0.000961 \times 10^{0.0251\,(t-1160)} - 0.001),$$

the development of which was based on Arrhenius' equation giving the relation of reaction rate to temperature. Because both time and temperature are factors of A_Σ, it expresses the amount of heat treatment.

The specimens were cooled at an average rate of about 10° per minute for the first 15 minutes of the cooling period. They reached a temperature of 600°C in about 3 hours and cooled to less than 100°C in 8 to 10 additional hours.

Because, in the usual heat treatment of these bodies, nearly all of the vitrifying action takes place at temperatures above 1100°C, the rate of heating below this temperature was not closely controlled in the case of bodies A, AF, B, and BF. In heating bodies A3 and K from room temperature to 1100°C, the temperature was increased at a rate within several degrees per hour of that specified in Table III, while for the range above 1100°C, the temperature in all cases was controlled within ±2° of that specified in the same table.

Both the dried and heat-treated specimens were weighed in air and in mercury and, using these weights, the volumes, bulk specific gravities, and shrinkages during heating were calculated. Heat-treated bars were boiled two hours and cooled overnight to determine apparent porosities. Transverse strength tests were made on a 2-inch span.

The changes in the glasses present in the heated specimens were studied with the aid of thin and of polished sections and of powdered samples obtained from the same specimens on which tests of physical properties had been made. Two constituents of the glass phase were designated as "clay-glass"† and feldspar-glass (areas *C* and *F*, Figs. 1 to 20) to indicate the minerals from which they were derived, while layers surrounding grains of glass and quartz (Fig. 17) were called "reaction glass." The portion of the glass phase which was composed of extremely minute, unidentifiable grains, chiefly glass, formed the matrix or ground-mass (the mottled areas of the photomicrographs).

† Decomposition of the hydrated minerals in clays at 550° to 600°C results in the formation of a material having random molecular arrangement,[14] being similar to glass in this respect.[15] In the present investigation, pseudomorphs of original clay particles were designated as "clay-glass" to contrast them with the crystalline constituents of the specimens.

The photomicrographs were made of thin sections, a magnification of 880 × being shown in all figures, except Fig. 8, in which it was 300 ×.

Measurements of the refractive index of the glasses were made on powdered samples of the test specimens, using the immersion method.

III. Results

Petrographic examinations of thin sections showed that the glass content of all the specimens was high. The identity of most of the clay and smaller particles of the feldspar was lost. Quartz was the chief crystalline material. Identification of the glasses was made from measurements of relative index of refraction. Inclusions in the glass grains and the shapes of the grains helped in the process of identification.

The average value of the index of refraction of clay-glass was 1.55, that of feldspar-glass 1.49, and that of dissolved quartz 1.46. Only slight variations in these values resulted from the extreme variations in heat treatment. Geller and Creamer[2] found that the glass phase had practically the same average index of refraction (1.486 to 1.490) in all bodies of a series heated in the range of cones 4 to 14. Rieke and Navratiel[16] showed that the value of the index of feldspar-

[13] W. W. Meyer, "Computation of Heat Treatments for Whiteware Bodies," *Jour. Amer. Ceram. Soc.*, **21** [3] 75–79 (1938).

[14] Herbert Insley and R. H. Ewell, "Thermal Behavior of the Kaolin Minerals," *Jour. Research Nat. Bur. Stand.*, **14** [5] 615–27 (1935); R. P. 792; *Ceram. Abs.*, **14** [8] 201 (1935).

[15] R. Houwink, Elasticity, Plasticity, and Structure of Matter, Chapt. VI, Glass. Cambridge Univ. Press, 1937. See also footnote reference 9(*b*).

[16] R. Rieke and H. Navratiel, "Ability of Porcelains to Stand Temperature Changes," *Ber. deut. keram. Ges.*, **11** [4] 231–45 (1930); *Ceram. Abs.*, **10** [3] 203 (1931).

TABLE III
HEAT TREATMENTS AND PHYSICAL PROPERTIES OF SPECIMENS

Body	Group	Set	Heat treatment: Temperature rise (°C/hr.)	Heat treatment: Final temperatures (°C)	Heat treatment: Time held (hr.)	$A\Sigma$	Properties: No. of bars	Properties: Bulk specific gravity of dried bars	Properties: Bulk specific gravity of heated bars	Properties: Volume shrinkage during heating (%)	Properties: Apparent porosity of heated bars (%)	Properties: Transverse strength of heated bars (lb./in.²)
AF	1	*a*	40	1260	0	0.13	5	1.87	[a]2.398 ± 0.004	26.8 ± 0.2	0.03 ± 0.03	9900 ± 300
		b	60	1267	0	.13	5	1.87	2.402 ± .004	27.0 ± .1	.05 ± .03	9900 ± 500
		c	90	1273	0	.13	5	1.87	2.406 ± .004	26.9 ± .1	.06 ± .05	10100 ± 400
		d	135	1280	0	.13	4	1.87	2.393 ± .005	26.6 ± .3	.05 ± .02	10100 ± 500
A	2	*a*	40	1260	0	.13	5	[b]1.89	2.386 ± .005	25.6 ± .4	.11 ± .04	8800 ± 500
		b	60	1267	0	.13	5	[b]1.89	2.386 ± .008	25.5 ± .4	.07 ± .02	9700 ± 300
		c	90	1273	0	.13	5	[b]1.89	2.390 ± .011	25.7 ± .4	.09 ± .03	9400 ± 500
		d	135	1280	0	.13	3	[b]1.88	2.375 ± .007	25.5 ± .3	.22 ± .10	8000 ± 400
A	3	*a*	20	1255	0	.20	4	[c]1.90	2.390 ± .005	25.3 ± .3	.16 ± .04	9700 ± 200
		b	27	1255	0	.15	4	[c]1.90	2.387 ± .004	25.2 ± .2	.20 ± .10	9600 ± 300
		c	40	1255	0	.10	4	[c]1.90	2.375 ± .005	24.8 ± .2	1.1 ± .2	8800 ± 400
		d	60	1255	0	.07	4	[c]1.90	2.365 ± .005	24.5 ± .2	2.3 ± .1	7000 ± 500
		e	135	1255	0	.03	4	[c]1.90	2.318 ± .004	22.9 ± .3	3.9 ± .4	6600 ± 500
A	4	*a*	30	1257	0	.15	4	[d]1.88	2.375 ± .005	25.5 ± .2	0.38 ± .06	9500 ± 400
		b	30	1240	1	.15	4	[d]1.88	2.384 ± .005	25.7 ± .3	.24 ± .07	9300 ± 400
		c	30	1218	5	.15	4	[d]1.88	2.386 ± .005	25.7 ± .2	.20 ± .10	9600 ± 200
		d	180	1246	1	.15	4	[d]1.88	2.377 ± .005	25.5 ± .2	.53 ± .08	9600 ± 200
		e	180	1220	5	.15	4	[c]1.90	2.387 ± .008	25.0 ± .2	.33 ± .10	9600 ± 400
A	5	*a*	30	1279	0	.5	3	[d]1.87	2.394 ± .011	26.2 ± .4	.18 ± .12	9700 ± 400
BF	6	*a*	40	1260	0	.13	4	1.88	2.238 ± .008	20.9 ± .3	7.7 ± .5	6400 ± 300
		b	60	1267	0	.13	4	1.88	2.245 ± .008	21.4 ± .2	7.4 ± .8	6300 ± 300
		c	90	1273	0	.13	4	1.88	2.250 ± .004	21.6 ± .1	6.8 ± .8	6700 ± 300
		d	135	1280	0	.13	6	1.88	2.226 ± .005	20.5 ± .3	7.0 ± .7	6200 ± 300
B	7	*a*	40	1260	0	.13	4	[b]1.88	2.193 ± .005	19.5 ± .2	8.8 ± .1	5900 ± 200
		b	60	1267	0	.13	4	[b]1.88	2.205 ± .011	19.9 ± .4	8.8 ± .3	5800 ± 500
		c	90	1273	0	.13	4	[b]1.88	2.218 ± .008	20.4 ± .4	8.7 ± .3	6200 ± 200
		d	135	1280	0	.13	6	[b]1.88	2.190 ± .009	19.2 ± .3	8.9 ± .5	5900 ± 200
B	8	*a*	20	1255	0	.20	4	[c]1.88	2.208 ± .005	19.6 ± .3	8.6 ± .3	6100 ± 200
		b	27	1255	0	.15	4	[c]1.88	2.200 ± .007	19.5 ± .2	8.7 ± .7	6200 ± 200
		c	40	1255	0	.10	4	[c]1.88	2.188 ± .008	19.1 ± .2	9.7 ± .5	6100 ± 100
		d	60	1255	0	.07	4	[c]1.88	2.165 ± .011	18.2 ± .5	10.9 ± .7	5800 ± 100
		e	135	1255	0	.03	4	[c]1.88	2.094 ± .011	15.2 ± .5	14.7 ± .7	5400 ± 200
B	9	*a*	30	1257	0	.15	4	[d]1.88	2.173 ± .005	18.5 ± .2	11.2 ± .2	5900 ± 100
		b	30	1240	1	.15	4	[d]1.88	2.178 ± .005	18.8 ± .3	10.8 ± .2	5700 ± 300
		c	30	1218	5	.15	4	[d]1.88	2.175 ± .009	18.7 ± .2	10.7 ± .3	5700 ± 300
		d	180	1246	1	.15	4	[d]1.88	2.183 ± .005	18.9 ± .4	10.9 ± .2	5900 ± 300
		e	180	1220	5	.15	4	[c]1.89	2.208 ± .005	19.2 ± .2	8.7 ± .4	5700 ± 100
B	10	*a*	30	1279	0	.5	3	[d]1.88	2.207 ± .007	19.9 ± .4	9.2 ± .3	6100 ± 200
A3	11	*a*	25	1252	3	.7	6	[b]1.87	2.405 ± .004	26.8 ± .3	0.03 ± .03	9800 ± 200
		b	50	1253	3	.7	11	[e]1.87	2.411 ± .004	27.2 ± .2	.04 ± .03	9700 ± 200
		c	75	1254	3	.7	11	[e]1.87	2.408 ± .003	27.1 ± .2	.03 ± .02	9400 ± 200
		d	100	1254	3	.7	11	[e]1.87	2.406 ± .003	26.9 ± .2	.03 ± .02	9300 ± 200
		e	125	1254	3	.7	15	[f]1.87	2.407 ± .003	27.0 ± .2	.01 ± .01	9600 ± 200
A3	12	*a*	50	1263	1½	.7	5	[d]1.87	2.406 ± .005	27.2 ± .2	.04 ± .04	9300 ± 500
		b	60	1267	1¼	.7	13	[g]1.87	2.405 ± .003	26.8 ± .2	.03 ± .02	9600 ± 200
		c	75	1270	1	.7	5	[d]1.87	2.404 ± .005	27.1 ± .2	.05 ± .02	9400 ± 500
		d	100	1275	¾	.7	5	[d]1.87	2.400 ± .005	26.9 ± .2	.03 ± .02	9200 ± 500
		e	125	1279	⅝	.7	5	[d]1.87	2.396 ± .005	26.9 ± .2	.04 ± .03	9400 ± 400
A3	13	*a*	25	1273	3	2.5	6	[c]1.87	2.394 ± .004	26.5 ± .4	.02 ± .02	8900 ± 300
		b	60	1289	1¼	2.5	3	[d]1.87	2.386 ± .004	26.5 ± .3	.02 ± .03	9000 ± 300
A3	14	*a*	[h]50	1253	3	.7	6	[b]1.87	2.408 ± .004	27.0 ± .4	.03 ± .02	9700 ± 300
		b	[i]35	1252	2½	.7	4	[d]1.87	2.409 ± .003	27.3 ± .2	.04 ± .03	9400 ± 300
		c	[k]43	1327	0	6.0	5	[d]1.87	2.285 ± .012	23.3 ± .3	.05 ± .03	6800 ± 500
K	15	*a*	75	1270	1	.7	5	1.85	2.413 ± .001	27.8 ± .1	.04 ± .03	9400 ± 200
		b	75	1249	1	.2	5	1.85	2.402 ± .003	27.5 ± .3	.06 ± .02	9500 ± 200

[a] ± values correspond to $P_s = 0.95$; see footnote reference 17.
[b] Batch No. 1.
[c] Batch No. 2.
[d] Batch No. 3.
[e] Av. of batches Nos. 1 and 3.
[f] Av. of batches Nos. 1, 2, and 3.
[g] Av. of batches Nos. 1 and 2.
[h] Heated first 1000°C at 25° per hr.
[i] Heated first 700°C at 25° per hr., then to 1267°C at 35° per hr., cooled quickly to 1252°C, and soaked.
[k] Heated first 900°C at 25° per hr., then at 43° per hr. to 1327°C.

glass (1.475) was increased slightly when saturated with kaolin (1.478).

The inclusions (black portions of *C* in Figs. 1, 4, and 14) in clay-glass grains were minute voids or sealed pores and short prisms of rutile. Inclusions in feldspar-glass were long needles of mullite, shown in areas *F* (Figs. 5 and 6), and spherical gas blebs (circular holes, *B*, in the thin sections of Figs. 2 and 6). Pseudocleavage cracks, frequently observed in clay-glass grains (parallel lines in area *C*, Fig. 1) and in feldspar-glass (intersecting lines in area *F*, Fig. 4), had the same respective arrangement as cleavage in the unheated minerals, kaolinite and feldspar.

The clay-glass grains varied considerably from minute, irregular-shaped particles to larger wedge-, lens-, and vermicular-shaped grains characteristic of certain particles often found in unheated kaolins. The outlines of feldspar-glass grains in general, were angular, resembling the shape of the unheated mineral. Pitting of the surfaces of these glass grains as well as expansion of inclosed gas blebs, however, caused alteration of their outlines. Small particles of quartz-glass were much rounded and were identified by their relatively low index of refraction and often by the presence of a crystalline core.

There were three distinct varieties of pores present in the bodies. Sealed pores in the clay-glass appeared as black specks in a brilliantly illuminated microscopic field. Larger irregular-shaped voids in the matrix, called "shrinkage pores," were best observed in polished sections. Spherical bubbles in the feldspar-glass constituted the third kind of pores.

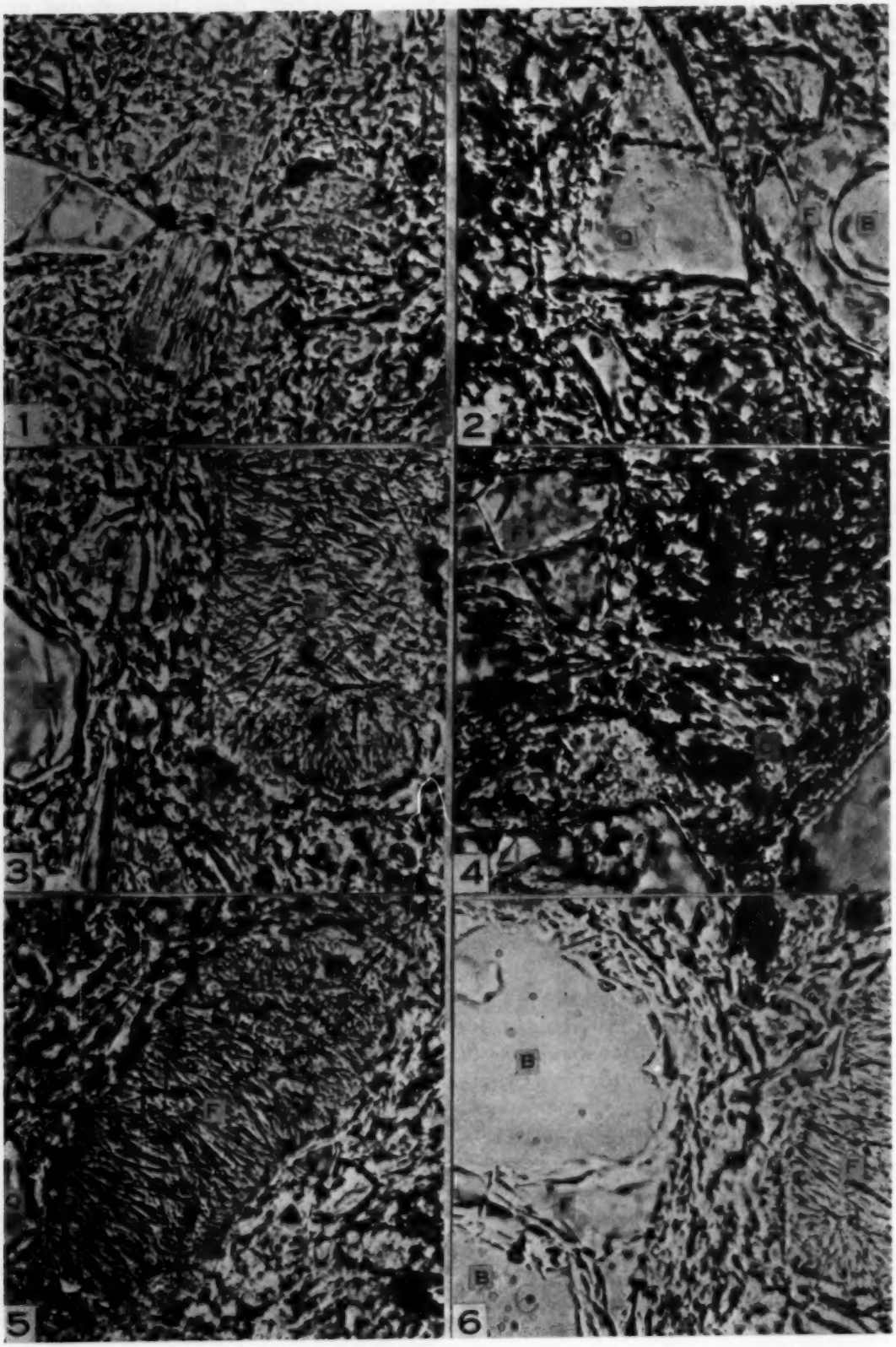
A description of the petrographic observations of the specimens according to groups in Table III follows. In these descriptions, the rates of temperature rise* are mentioned, but final calculated temperatures, which depend on the values of A_Z, are not often referred to. Efforts were made to include in the photomicrographs the chief characteristics of the microstructure of the specimens. Not all of the observations made on a single thin section, however, could be illustrated in one photomicrograph.

The vitreous specimens in group 1, containing fine feldspar, were heated to show the effects of more rapid rates of temperature rise (column 4, Table III) with no soaking, giving $A_Z = 0.13$ (approximate vitrification range, $A_Z = 0.17$ to 1.7). Set 1*a* (40° per hour) had the structure shown in Fig. 1. The matrix was uniformly mottled, with relatively few sealed pores present. The feldspar-glass grains with hazy outline contained much fine mullite. The rounded clay-glass grains contained small amounts of rutile and a few pseudocleavage lines. Quartz grains were slightly rounded. Sets 1*b* (60° per hr.) and 1*c* (90° per hr.) contained more sealed pores of reduced size than were found in 1*a*, making the matrix more mottled in appearance than shown in Fig. 1. The outlines of feldspar-glass grains were more distinct and the amounts of mullite less than in 1*a*. These changes were more pronounced in 1*d* (135° per hr.) as shown in Fig. 2. The matrix was darker and contained more sealed pores and fine fragments of crystalline material than shown in Fig. 1. Feldspar-glass grains (Fig. 2) had sharp outlines, and many contained blebs but little or no mullite. The clay-glass was very mottled with irregular outline showing little diffusion.

The vitreous specimens in group 2 contained commercial feldspar and were heated identically with those in group 1 (approximate vitrification range, $A_Z = 0.17$ to 1.7). Set 2*a* (40° per hr.) had structures much like that shown in Fig. 1, except for larger grains of feldspar-glass, more sealed pores, and less diffusion of clay- and feldspar-glasses. With more rapid heating rates, effects similar to those observed in group 1, but more pronounced, were noted.

The vitreous specimens in group 3 were heated at more rapid rates to a constant final temperature to show the effects of decreasing values of A_Z. Set 3*a* (20° per hr.) shown in Fig. 3, when compared with set 1*a*, which contained fine feldspar (40° per hr., Fig. 1), had relatively fewer sealed pores and their size was somewhat larger than in 1*a*. The matrix was more mottled, the quartz grains were more rounded, and the mullite needles in the feldspar-glass were longer and more abundant. A greater contrast was found in the microstructure of the sets in group 3 than those in groups 1 and 2. Set 3*e* (Fig. 4, 135° per hr.) con-

* The rate of heating adopted for a given set of specimens was maintained practically constant during the temperature rise above 1100°C. The rate used in heat-treating the first set of specimens in a group (Table III) was made the basis of comparison, more rapid heating rates being employed in treating successive sets in that group. Consequently, in this report, such an expression as "more rapid heating rates" does not indicate an accelerated rate during the temperature rise.



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tained less glass than any other of the vitreous specimens. The matrix was extremely mottled and contained numerous crystalline fragments and sealed pores. The grains of feldspar-glass were sharply outlined, containing little or no mullite and some blebs. Pseudocleavage cracks were prominent. Clay-glass grains contained numerous rutile prisms and sealed pores (black areas). Quartz grains were apparently unaffected.

The vitreous specimens in group 4 were heated to show the effects of slow and rapid heating rates, followed in each case by a short and a long soaking period, with $A_z = 0.15$. Set 4*a*, not soaked, had a microstructure resembling that of 3*a* (Fig. 3). Sets 4*b* and 4*c* (heated at 30° per hr. and soaked 1 hr. and 5 hr., respectively) had a less mottled matrix and fewer sealed pores, but more diffusion of clay- and feldspar-glasses, more solution of quartz, and more mullite than set 4*a* (not soaked). After 5 hours' soaking (Fig. 5), a few blebs in the matrix and a small amount of very fine mullite needles (not shown in Fig. 5) in the clay-glass were found. Sets 4*d* and 4*e* (180° per hr.) exhibited typical effects of rapid heating rates, such as numerous pores and blebs in the feldspar-glass (Fig. 6). Because of the soaking they also showed effects resembling those of slow-heating rates, such as diffusion of feldspar-glass, well-developed mullite needles, and solution of quartz. These effects of soaking were greater after 5 hours than 1 hour.

The vitreous specimens in group 5 were heated with no soaking to show the effects of increasing A_z from 0.15 to 0.5. Set 5*a* (Fig. 7) had a structure much like that of 4*c* (Fig. 5), but there were no blebs in the matrix and no mullite needles in the clay-glass.

The semivitreous specimens in group 6, containing fine feldspar, were heated simultaneously with the vitreous specimens in group 1, giving $A_z = 0.13$. The presence of larger quantities of quartz and of small amounts of glass phase in the semivitreous specimens resulted in clearer microscopic fields compared with those from vitreous specimens (Fig. 8).

Specimens in set 6*a*, heated at 40° per hour, had the structure shown in Fig. 9. There were relatively few sealed pores but numerous shrinkage pores (determined in polished sections). The feldspar-glass grains showed about the same mullite content but less diffusion into the matrix than was observed in set 1*a* (Fig. 1). The clay-glass grains also had less rounded corners and contained more undissolved rutile (black specks) than in 1*a* specimens. The changes in the semivitreous sets, 6*b*, 6*c*, and 6*d*, for the respective heating rates of 60°, 90°, and 135° per hour, were somewhat similar to those described for sets 1*b* 1*c*, and 1*d*, except for a greater increase in shrinkage pores and the formation of less mullite. The structure of 6*d* heated at 135° per hour is shown in Fig. 10. When present, mullite was near the surface of feldspar-glass grains.

The semivitreous specimens in group 7 contained commercial feldspar and were heated simultaneously with specimens in group 2. The specimens had more pores, showed less diffusion of clay- and feldspar-glass and less solution of quartz than specimens in group 6, which contained fine feldspar.

The semivitreous specimens in group 8 were heated simultaneously with group 3 specimens. Set 8*a* (20° per hr.) had larger sealed pores, more mullite, and greater diffusion of feldspar-glass and rounding of quartz grains than set 6*a* (40° per hr.), as shown by comparison of Fig. 11 with Fig. 9. The amount of glass decreased and the mottled appearance of the matrix increased in sets 8*b*, 8*c*, 8*d*, and 8*e* as their respective heating rates were increased. Set 8*e* (Fig. 12) contained less glass than any other studied. The

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FIG. 1.—Microstructure of set *a* (group 1) heated at 40° per hr. to 1260°C; mottled matrix constitutes chief area; black spots, somewhat rounded, are sealed pores; areas *C* and *F* indicate clay-glass and feldspar-glass, respectively.

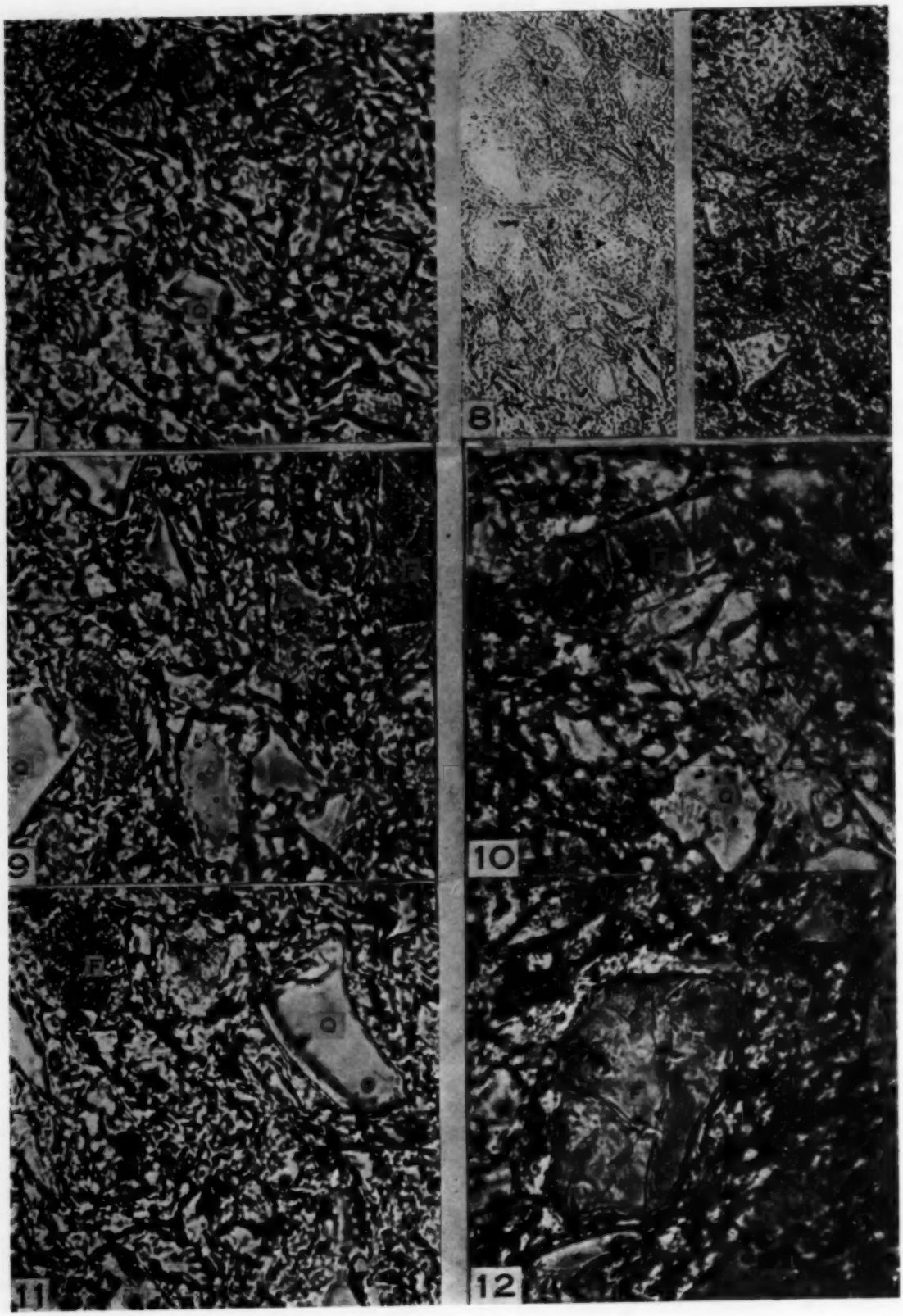
FIG. 2.—Microstructure of set *d* (group 1), heated at 135° per hr. to 1280°C; larger black spots in the matrix are sealed pores; feldspar-glass, *F*, contains gas bubble, *B*.

FIG. 3.—Microstructure of set 3*a*, heated at 20° per hr. to 1255°C; mottled matrix contains few sealed pores; feldspar-glass, *F*, has hazy outline and contains numerous mullite needles.

FIG. 4.—Microstructure of set 3*e*, heated at 135° per hr. to 1255°C; matrix appears extremely mottled and contains numerous sealed pores and crystalline particles of rutile; triangular-shaped clay-glass grain, *C*, and feldspar-glass, *F*, show lack of diffusion.

FIG. 5.—Microstructure of set 4*c*, heated at 30° per hr. and soaked 5 hr. at 1218°C; diffusion shown by faint outline of feldspar-glass, *F*, and presence of numerous mullite needles; quartz grain, *Q*, rounded; large sealed pore, black, at lower right corner.

FIG. 6.—Microstructure of set 4*d*, heated at 180° per hr.; soaked 1 hr.; matrix contains enlarged sealed pores (black spots); one feldspar-glass grain, *F*, contains numerous mullite needles; a second grain contains two large gas bubbles, but no mullite.



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effects on these specimens of variations in heating schedules appeared to be greater than on vitreous specimens.

The semivitreous specimens in group 9 were heated simultaneously with the specimens in group 4. Set 9*a* (heated at 30° per hr. and not soaked) had a structure similar to 8*b*, having received approximately the same heat treatment. Sets 9*b* and 9*c* (heated at 30° per hr. and soaked 1 hr. and 5 hr., respectively) showed more diffusion of glasses and greater solution of quartz and rutile than in 9*a*, the changes being more marked in 9*c* (Fig. 13) than in 9*b*. In set 9*d* (180° per hr., soaked 1 hr.; Fig. 14), the matrix was very mottled, sealed, and shrinkage pores were abundant and little diffusion of clay-glass grains and solution of rutile (black spots in *C*) had taken place. Blebs in feldspar-glass were plentiful, but mullite needles were larger and more abundant than in the semivitreous set 6*d*, which was heated rapidly and not soaked (Fig. 10). Less diffusion of glasses and less mullite growth, however, were found in 9*d* than in the identically heated vitreous set 4*c* (Fig. 5).

The semivitreous specimens in group 10 were heated simultaneously with the specimens in group 5. Set 10*a* (Fig. 15) had a greater glass content than was found in 8*b* and was similar to 9*c* (Fig. 13) in glass content and general structure.

The vitreous specimens in group 11 were heated to show the effects of a 3-hour soaking period following five different rates of temperature rise, with $A_\Sigma = 0.7$ (approximate vitrification range, $A_\Sigma = 0.19$ to 1.9). The specimens of the entire group had remarkably uniform microstructure, that of set 11*a* (heated at 25° per hr., Fig. 16) being characteristic of all the specimens. Blebs in the feldspar-glass of 11*e* (Fig. 17) were the only indication of the rapid heating rate, 125° per hr.

The vitreous specimens in group 12 were heated to show the effects of shortening the time of heat treatment by using more rapid rates and at the same time proportionately shorter soaking periods with $A_\Sigma = 0.7$. The specimens showed a lack of the uniformity exhibited by those in group 11. The microstructure of set 12*b* (heated at 60° per hr., soaked $1^1/_4$ hr., Fig. 18) showed less diffusion of glasses and less solution of quartz and rutile as well as smaller quantities of mullite than were found in 11*a* (Fig. 16). In set 12*e* (Fig. 19), heating at 125° per hr. with a $^3/_8$-hr. soaking period resulted in increased numbers of sealed pores and blebs and decreased quantities of mullite compared with 12*a* (heated at 50° per hr., soaked $1^1/_2$ hr).

The vitreous specimens in group 13 were heated to $A_\Sigma = 2.5$, slightly above the safe upper limit of the vitrification range, $A_\Sigma = 1.9$. The glass content of the specimens was high, with marked diffusion of the glasses and solution of quartz. Mullite was well developed. In addition to numerous blebs in the feldspar-glass, they were also present in the matrix.

The vitreous specimens in group 14 were heated to show the effects of various changes in the rates of heating during the temperature rise as well as certain changes in final temperature. Sets 14*a* and 14*b* had microstructures similar to those in group 11 (Fig. 16). Set 14*c* (heated to $A_\Sigma = 6.0$, Fig. 20, well above the vitrification range) showed a larger increase in the number of blebs in the matrix and in feldspar-glass. In expanding, many blebs had apparently united to form a single large, irregular-shaped void. Increases of mullite, diffusion of glasses, and solution of

FIG. 7.—Structure of set 5*a*, heated at 30° to 1279°C; outline of feldspar-glass grain (upper left corner) practically lost; mullite coarse and abundant; matrix appears uniformly mottled with few sealed pores; quartz (*Q*) rounded.

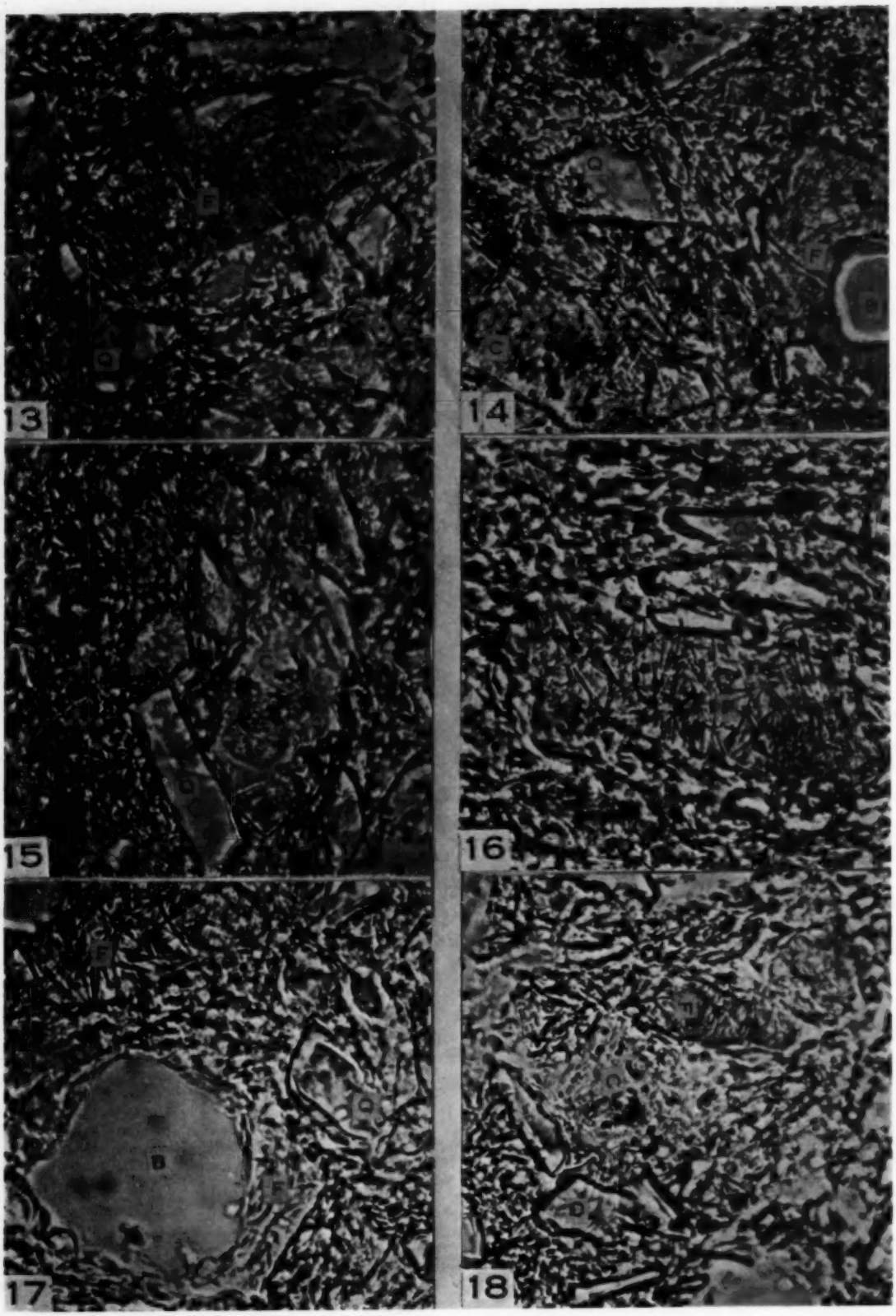
FIG. 8.—Lighting conditions and a magnification of 300× chosen to emphasize general appearance of thin sections; characteristic mottled field of vitreous specimen shown right, and clear field of semivitreous specimen, left (300×); different lighting conditions and a higher magnification (880×) employed in making the other photomicrographs to show structural details.

FIG. 9.—Structure of semivitreous set 6*a*, containing fine feldspar, heated at 40° per hr. to 1260°C; matrix contains fewer sealed pores (black spots) than Fig. 10; feldspar-glass, *F*, has fairly sharp outline and contains numerous fine mullite needles; clay-glass grain, *C*, contains small, black, rutile fragments.

FIG. 10.—Microstructure of semivitreous set 6*d*, heated at 135° per hr. to 1280°C; sealed pores (black spots) in matrix are fairly numerous (compare with Figs. 9 and 2); feldspar-glass grain, *F*, shows pseudocleavage cracks and lack of diffusion by sharp edges and no mullite.

FIG. 11.—Microstructure of semivitreous set 8*a*, heated at 20° per hr. to 1255°C; matrix contains more sealed pores than in specimen made with fine feldspar (compare black spots with those in Fig. 9); feldspar-glass, *F*, filled with mullite.

FIG. 12.—Microstructure of semivitreous set 8*e*, heated at 135° per hr. to 1255°C; numerous small sealed pores and tiny rutile fragments produce a very speckled matrix; reaction of feldspar-glass, *F*, with surrounding matrix frequently observed, is well shown by penetration of reaction glass with the apparent separation of flakes (in thin section) around the surface.



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quartz were also found. The glass content was very high.

The vitreous specimens in group 15 showed the effects of substituting a clay containing larger amounts of fine-grained material than that used in the preceding bodies. The matrix of sets 15*a* and 15*b* was less mottled in appearance and contained smaller clay-glass particles than any other specimens examined. Very few sealed pores were found.

The results of determinations of various physical properties are given in Table III. The plus or minus (±) values in this table were calculated by the method recommended by the American Society for Testing Materials,[17] using $P_s = 0.95$; *i.e.*, 95 out of 100 repeat determinations would be expected to fall within the ranges indicated by the plus or minus values, according to statistical probability. The significance of differences between averages was determined, using the ratio,

$$\frac{\bar{x}_1 - \bar{x}_2}{\sqrt{r_1^2 + r_2^2}}.$$

Where $\bar{x}$ = average value.
r = error (± value) of the average.
Denominator = error of difference between averages.

Under the stated conditions, when the ratio equals one, there are 19 chances in 20 that the difference is not due to nonsystematic errors, and it is considered significant. If the ratio equals 1.5, there are 997 chances in 1000 that the difference is not due to chance errors, and it is considered highly significant.

[17] (*a*) American Society for Testing Materials, Manual for Interpretation of Refractory Test Data, p. 87, February, 1935.
(*b*) *Ibid.*, Manual on Presentation of Data, pp. 40–41, 1933. 2d printing, March, 1937.

IV. Discussion

(1) The Glassy Matrix

The process of vitrification involves the progressive development of glass phases throughout the body. The appearance of the glassy matrix begins with the dehydration of the clay. Because of the fineness of grain, the platy structure of the original clay, and the amorphous state of the heated clay, the latter is more active chemically[18] than the other body constituents at 600°C, as has been shown by its solution in hot sulfuric acid.[19] In the assumption frequently made by other investigators that feldspar-glass is the first to be formed by the heat treatment, the dehydrated clay is not considered as glass.

(2) Reactions of Clay-Glass

The small quantities of glass formed from the reaction of clay-glass with adsorbed salts and impurities in the clays were increased by another type of glass produced at points of contact between clay-glass particles and those of adjacent minerals. As the temperature was increased to 1160°C and higher, larger quantities of reaction glass formed layers, which coated both glass and crystalline grains. Schramm and Hall[20] point out that a simple solvent action could not account for all changes of body properties and that feldspar is only one of the materials involved in glass-forming reactions. Diffusion takes place between adjacent particles through the layers of reaction glass. The mechanism of

[18] O. Krause, "Studies of Structure of Hard Porcelain," *Z. tech. Physik*, **9** [7] 247–63 (1928); *Ceram. Abs.*, **8** [2] 133 (1929).
[19] A. V. Bleininger, "Solubility of Fired Bodies in Hot Sulfuric Acid," *Jour. Amer. Ceram. Soc.*, **10** [7] 535–37 (1927).
[20] E. Schramm and F. P. Hall, "Fluxing Effect of Feldspar in Whiteware Bodies," *Jour. Amer. Ceram. Soc.*, **19** [6] 159–68 (1936).

FIG. 13.—Microstructure of semivitreous set 9*c* heated at 30° per hr. and soaked 5 hr. at 1218°C; matrix contains smaller number of sealed pores than shown in Fig. 14; feldspar-glass grain, *F*, shows layers of reaction glass on upper and lower sides, and contains more mullite than found in Fig. 14.

FIG. 14.—Microstructure of semivitreous set 9*d*, heated at 180° per hr. and soaked 1 hr. at 1246°C; bleb, *B*, and scattered needles of mullite shown in feldspar-glass grain, *F*; clay-glass grain, *C*, contains an unusual number of rutile particles.

FIG. 15.—Microstructure of semivitreous set 10*a*, heated at 30° per hr. to 1279°C; sealed pores (black spots) in matrix are enlarged as compared with those in Figs. 9 and 11; clay-glass particle, *C*, shows clear reaction layer near surface with central portion still containing small rutile particles.

FIG. 16.—Set 11*a*, heated at 25° per hour to 1252°C and soaked 3 hr.; uniformly mottled matrix contains two enlarged sealed pores; feldspar-glass grain, *F*, filled with mullite has practically lost its outline.

FIG. 17.—Set 11*e*, heated at 125° per hr. to 1254°C and soaked 3 hours; shows bleb, *B*, which apparently has expanded from the feldspar-glass grain, *F*, into the matrix; another feldspar-glass grain has no outline and is filled with mullite; quartz grain, *Q*, shows surrounding layer of reaction glass.

FIG. 18.—Set 12*b*, heated at 60° per hr. to 1267°C and soaked for 1¼ hr., $A\Sigma = 0.7$; matrix is uniformly mottled with few sealed pores; feldspar-glass grain, *F*, surrounded by reaction layer contains numerous fine mullite needles; clay-glass grain, *C*, contains some undissolved rutile.

ion migration in glass without appreciable breakdown of the framework has been shown by Zachariasen.[21] Forces, probably surface tension, acting in these layers of reaction glass, draw the particles together and close the interstitial spaces between them.

(3) Mullite and Blebs in Feldspar-Glass

In specimens heated above 1160°C, coarser grains of feldspar furnished a glass in which the best development of mullite occurred. Insley[22] showed that at body-glaze contact longer needles of mullite were formed in the less viscous glaze than in the more viscous glass phase of the body. In the present experiments, absence of mullite in some of the feldspar-glass grains was considered indicative of relatively higher viscosity than that of nearby grains filled with mullite (Fig. 6). The presence of blebs in these mullite-free, feldspar-glass grains supported this assumption, inasmuch as the gas was retained by grains of apparently higher viscosity but escaped from those of supposedly lower viscosity. Local impurities in feldspar may have caused the differences in viscosity of individual grains.

Apparently the amount of mullite formed in the feldspar-glass depended not only on the viscosity of the latter, but also on the time afforded for molecular diffusion from clay-glass. The time for diffusion seemed to be a more important factor than the viscosity, as evidenced by the lack of mullite in feldspar-glass of rapidly heated specimens. Only mullite-free, feldspar-glass grains were found in set 3*e* (Fig. 4, heated at 135° per hour), and only mullite-filled grains in set 3*a* (Fig. 3, heated at 20° per hour). Inasmuch as the final temperatures of both sets were 1255°, doubtless the viscosity of the feldspar-glass was constant in the two sets. The viscosity of the feldspar-glass[23] precludes the assumption that it is disseminated by flowing through the interstices between the mineral particles.

Bubbles in the feldspar-glass were caused by the evolution of dissolved gases.[24] The gradual escape of some of these gases during a slow temperature rise accounted for the scarcity of bubbles. The greater numbers of blebs formed, when heating was continued near or above the upper limit

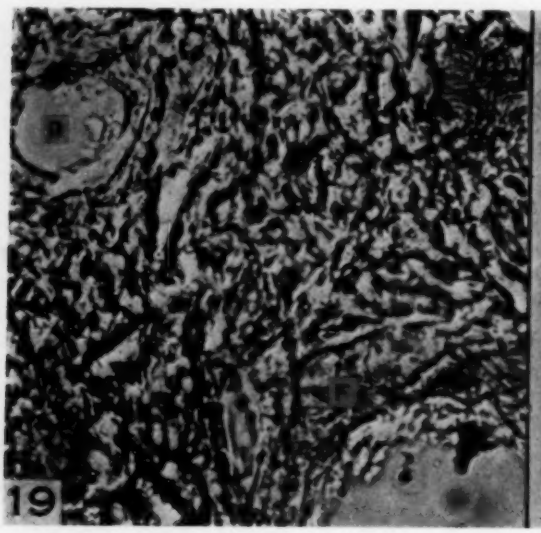

FIG. 19.—Set 12*e*, heated at 125° per hr. to 1279°C and soaked ½ hr., $A\Sigma = 0.7$; blebs, *B*, and fine mullite shown in feldspar-glass, *F*; matrix more mottled and contains more sealed pores than in 12*b* (Fig. 18).

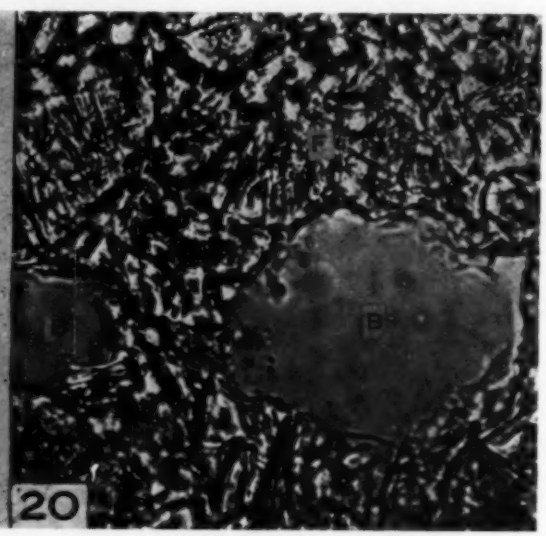

FIG. 20.—Set 14*c* heated at 25° and 43° per hr. to 1327°C with no soaking period; two blebs, *B*, in matrix and mullite in feldspar-glass grain, *F*, are shown.

[21] W. H. Zachariasen, "Atomic Arrangement in Glass," *Jour. Amer. Chem. Soc.*, **54**, 3841–51 (1932).

[22] Herbert Insley, "Microstructure of Earthenware," *Jour. Amer. Ceram. Soc.*, **10** [5] 317–26 (1927).

[23] W. M. Cohn, "Viscosity Measurements of Feldspar Melts at High Temperatures," *Ber. deut. keram. Ges.*, **15** [11] 551–58 (1934); *Ceram. Abs.*, **14** [6] 152 (1935).

[24] G. R. Shelton and H. H. Holscher, "Gases Obtained from Commercial Feldspars Heated in Vacuo," *Bur. Stand. Jour. Research*, **8** [3] 347–56 (1932); R. P. 420; *Ceram. Abs.*, **11** [6] 391 (1932).

of the vitrification range, were caused by the continued evolution of gas. Shelton and Holscher's experiments[24] showed that not all the dissolved gases in some commercial feldspars were evolved when heated in vacuo at 1000°C. In rapidly heated specimens, insufficient time for the gradual escape of gas resulted in the production of numerous bubbles of varying size, amounting in many particles almost to a frothy condition.

(4) Relation of Physical Properties to Vitrification Range

Specimens were considered to have optimum physical properties when relative bulk specific gravity, shrinkage, and strength were maximum. It was these optima of properties, especially the first, since its determination could be made with the most precision, with which values of A_z, corresponding to the middle of the vitrification range of the vitreous bodies, were correlated in a previous investigation.[13]

(5) Effects of Heating Rate with Constant A_z (0.13) Approximately at Bottom of Vitrification Range

Certain groups of specimens in Table II were considered together in correlating the effects of variation of heat treatment on the glass phase and physical properties. In groups 1, 2, 6, and 7, 90°C per hour seemed to be a critical rate of heating. Changing the rate from 40° to 90°C per hour produced sealed pores so much smaller that, in spite of their larger numbers, the changes were apparently directly related to the increased bulk specific gravity (trends in group 2) of these specimens. Between 90° and 135°C per hour, however, the decreased bulk specific gravity in groups 1, 6, and 7 (trend in group 2) accompanied the large increase in numbers of sealed pores and blebs. In general, a reversal of the other properties also occurred at the 90° per hour rate. For example, shrinkages increased between 40° and 90° per hour but decreased between 90° and and 135° per hour (trends in groups 1 and 2). Strengths tended to increase between 40° and 90°, but decreased (except in group 1) between 90° and 135° per hour. The apparent porosity tended to decrease in groups 2, 6, and 7 between the 40° and 90° per hour rates, but to increase between 90° and 135° per hour. While 135° per hour, with no soaking, resulted in no serious damage to the specimens, 90° per hour was the most rapid rate employed which produced only slightly undesirable effects on the glass phase and physical properties of vitreous and semivitreous specimens. The formation of larger amounts of reaction glass in the specimens of groups 1 and 6, containing fine feldspar,[25] was doubtless responsible for the production of a less heterogeneous glassy matrix and fewer sealed pores and slightly superior properties, compared with specimens in groups 2 and 7 which contained commercial feldspar. Therefore, somewhat more rapid heating rates could be employed with bodies containing fine feldspar (compare specific gravity and shrinkage of specimens 1*d* and 6*d* with 2*c* and 7*c*).

The formation of larger numbers of interstitial pores of reduced size, with more rapid heating rates, was probably due to more rapid compaction, resulting in less reorientation of the particles. This may be an indication of a less viscous reaction glass than that in slowly heated specimens, where increased diffusion of clay- and quartz-glass occurred.

(6) Effects of Slow and Fast Heating Rates with 0, 1, and 5 Hours' Soaking, Constant A_z (0.15)

The extremes of heat treatment employed in groups 4 and 9 produced marked effects on the glass phase but little or no change in the physical properties of the specimens. The effect of soaking was illustrated in set 4*b*. The increased amount of mullite and fewer sealed pores in the matrix of the specimens doubtless influenced their increase in bulk specific gravity compared with set 4*a*, which was not soaked. Increased numbers of blebs, resulting from prolonged soaking in sets 4*c* and 9*c*, may have counteracted the effects on density caused by increased amounts of mullite. Contrasted with the heat treatment of sets 4*b*, 4*c*, 9*b*, and 9*c*, heating at 180° per hour and soaking caused negligible injurious effects to sets 4*d*, 4*e*, 9*d*, and 9*e*. These experiments showed the wide latitude in rates of heating, in final temperatures, and in time of soaking which could be employed with little consequent change in body properties regardless of considerable alteration of the glass phase, when A_z is constant.

(7) Effects of Heating Rate with 3 Hours' Soaking, Constant A_z (0.7), Approximately at Middle of Vitrification Range.

Soaking vitreous specimens for 3 hours with $A_z = 0.7$ (group 11) resulted in remarkable uni-

[25] R. F. Geller, D. N. Evans, and A. S. Creamer, "Effects of Particle Size of a Potter's 'Flint' and a Feldspar in Whiteware," *Bur. Stand. Jour. Research*, **11** [3] 327–40 (1933); *Ceram. Abs.*, **12** [12] 427 (1933).

formity of glass phase and physical properties, compared with group 4 ($A_\Sigma = 0.15$). The most pronounced visible change in the glass phase, occurring between the rates 100° and 125° per hour, did not correlate with the changes in bulk specific gravity and volume shrinkage. These properties increased between 25° and 50° per hour and decreased between the 50° and 100° rates, but they were the same for the slowest and fastest rates used.

(8) Effects of Shortening Heat Treatment, Constant A_Σ (0.7)

Using more rapid heating rates and simultaneously decreasing the soaking time and increasing the final temperatures to make $A_\Sigma = 0.7$ (group 12) caused increased lack of uniformity of the matrix but no significant difference in the physical properties of any of the sets heated at rates of 25° to 100° per hour and soaked 3 to $^3/_4$ hour (sets 11*a* and 12*a* to 12*d*). The bulk specific gravity of set 12*e* (125° per hour, soaked $^3/_5$ hour), however, was significantly less than the bulk specific gravities of sets 11*a* and 12*a* to 12*c*. No change with decreasing soaking time occurred until a reduction was made from 3 to $^3/_4$ hr. (compare sets 11*d* and 12*d*) and from 3 to $^3/_5$ hr. (compare sets 11*e* and 12*e*), when a decrease in the bulk specific gravity was found. These experiments indicated that, at least within the vitrification range, the injurious effects of even a 125° per hour heating rate and soaking time of $^3/_5$ hour were small and were due more to the short soaking time than to the fast heating rate.

(9) Relation of Properties to A_Σ

A definite relation of values of A_Σ, of the glass phase, and of physical properties to the vitrification range of vitreous bodies, A, A3, and K, was found. Increasing A_Σ from 0.03 to 0.07 (sets 3*e* to 3*d*) in the region below the approximate lower limit ($A_\Sigma = 0.17$) of the vitrification range resulted in more glass formation, increased bulk specific gravity and shrinkage, and decreased porosity, but no significant change in strength. From $A_\Sigma = 0.07$ to 0.10 (3*d* to 3*c*), these changes continued and, in addition, strengths increased. The changes became marked as the beginning of the vitrification range was approached by increasing A_Σ from 0.10 to 0.15 (3*c* to 3*b*). Proceeding to $A_\Sigma = 0.2$ (set 3*a*), slightly above the lower limit of the vitrification range, resulted in fewer sealed pores and more mullite in the glass phase, but no change in physical properties. As A_Σ was raised, however, from 0.20 to 0.70 (sets 3*a* to 11*a*), $A_\Sigma = 0.70$, being the middle of the vitrification range for body A3, bulk specific gravity and shrinkage increased, porosity decreased, but no significant change in strength took place. With a further rise in the value of A_Σ from 0.70 to 2.5, that is, passing from the middle to above the approximate safe upper limit ($A_\Sigma = 1.9$) of the vitrification range (sets 11*a* to 13*a*), larger amounts of glass containing numerous blebs caused lower values of bulk specific gravity, shrinkage, and strength. These deleterious effects became large when the value of A_Σ reached 6.0 well above the upper limit of the vitrification range (set 14*c*).

(10) Difference in Effect of Varying Heat Treatment on Vitreous and Semivitreous Bodies

Because semivitreous bodies were obviously heated below their vitrification range, greater effects on the glass phase and properties might be expected to occur, compared with vitreous bodies heated simultaneously. Comparison of groups 8 and 3 shows that this supposition is correct.

(11) Adherence to Heating Schedule

Strict adherence to heating schedules was necessary only with limitations. As long as the departure was known and compensated for by the time the end of the treatment was reached, no significant changes occurred in the microstructure and physical properties of specimens (14*a* and 14*b*)

(12) Effect of Types of Kaolin

The effects of using a kaolin having smaller amounts of material in the larger particle sizes than that ordinarily employed (set 15*a* compared to 12*c*) were similar to those resulting from the use of fine feldspar, *i.e.*, less mottled matrix and increased bulk specific gravity.

V. Conclusions

(1) Variations in heat treatment affected the microstructure of the bodies studied more than they affected any of the physical properties as determined. Of the latter, bulk specific gravity could be determined most precisely and was, therefore, the most useful in correlations.

(2) With A_Σ constant, more rapid heating rates promoted (*a*) the formation of an apparently less viscous reaction glass which tended to improve the physical properties and (*b*) a greater number of sealed pores and blebs having the opposite effect. At a heating rate of over 90°C per

hour, the predominance of (*a*) must have been replaced by that of (*b*).

(3) Soaking specimens one hour tended to eliminate any injurious effects on the glass phase and physical properties resulting from fast heating, even when the rate was 180°C per hour. Less than one hour's soaking was insufficient, while more than one hour resulted in little improvement.

(4) Changes in microstructure and physical properties of vitreous bodies accompanying changes in A_Σ were more pronounced both above and below the vitrification range than within it.

(5) Increased fineness of feldspar or clay resulted in the formation of larger amounts of reaction glass, fewer closed pores, and better physical properties, which indicated that faster heating rates could be used. With finer raw materials, a wider vitrification range was also indicated.

(6) The improvement of body properties, shown by the laboratory tests, with faster heating rates and consequent formation of an apparently less viscous reaction glass, indicated the desirability of using both finer materials and faster heating rates.

(7) Strict adherence to heating schedules was unnecessary, if proper corrections to maintain a predetermined value of A_Σ were made before the end of the heat treatment.

National Bureau of Standards
Washington, D. C.

PYROMETRIC PROPERTIES OF SPODUMENE-FELDSPAR MIXTURES*

By J. E. Boyd, Jr.

Abstract

An experimental study is reported on pyrometric properties of mixtures of potash feldspar, soda feldspar, and spodumene. Numerical and graphic data show that the addition of spodumene to the feldspars up to 20% lowers the P.C.E. of the mixtures very rapidly. As spodumene is increased above 40%, the P.C.E. of the mixtures increases rapidly. By means of a triaxial diagram a considerable area is shown with P.C.E. values six to seven cones below those of the feldspars.

I. Introduction

Tests made in connection with studies on the concentration of spodumene from a pegmatite containing feldspar, quartz, and spodumene as the principal minerals, showed that mixtures of feldspar and spodumene have fusion temperatures as much as six to seven cones below feldspar. In these tests, spodumene proved to be considerably more refractory than feldspar. A cone molded from the fine-ground powder was barely sintered when heated to standard cone No. 12. The test cone, however, had expanded very appreciably. This phenomenon of expansion is taken advantage of in a method for concentration of spodumene developed by the Bureau of Mines.[1]

This investigation was conducted to obtain data on fusion properties of spodumene-feldspar mixtures.

II. Experimental

To compare data both on potash and soda feldspar, the triaxial system was used. Points at 10% intervals between the three materials were investigated. The triaxial diagram is shown in Fig. 2, giving the order of the numbering of the points. No mixtures containing more than 75% spodumene were tested because these mixtures have a higher P.C.E. than could be reached in the kiln used.

The spodumene was sorted by hand from pegmatite obtained from the North Carolina Kings Mountain district. It was crushed to $-1/2$ inch and all pieces containing impurities were discarded. The crushed material was then calcined to 2100°F to convert the material to beta-spodumene. This beta-spodumene does not expand noticeably upon further heating. The calcined product was then ground in a laboratory porcelain pebble mill to 230-mesh.

The two samples of feldspar used were likewise carefully selected, crushed, and ground to the same mesh.

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* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 29, 1938 (White Wares Division). Received February 11, 1938.

[1] Foster Fraas and Oliver C. Ralston, "Beneficiation of Spodumene by Decrepitation," *U. S. Bur. Mines Rept. of Invest.*, No. 3336 (1937).

To be sure the three materials were of the same fineness, particle-size distribution tests were made, and differences in grinding were corrected by further grinding of the coarser samples until all of them corresponded closely. Curves in Fig. 1 show the particle-size distribution of the three samples.

Chemical analyses of the three materials are given in Table I.

TABLE I

	Spodumene	Potash feldspar	Soda feldspar
SiO_2	63.84	66.72	66.22
Al_2O_3	28.61	18.52	21.76
Fe_2O_3	0.19	0.08	0.04
CaO	0.04	0.30	2.06
MgO	Trace	Trace	Trace
K_2O	0.00	12.10	0.41
Na_2O	0.00	1.82	9.37
Li_2O	7.26	0.00	0.00
Ignition loss	0.16	0.36	0.16
	100.10	99.90	100.02

All fusion tests were made in a muffle-type, gasoline-fired laboratory test kiln equipped with a pyrometer and suitable peephole for observing the cones as they deformed. The temperature was taken up rapidly to 1500°F after which it was increased at the rate of 300°F per hour. Several fusions were made. These were heated as nearly on the same schedule as was practical.

All test cones were made to conform in size and shape to standard Orton cones. The test cones were set in fireclay pats at an angle of 82° from the horizontal and were placed in the kiln about six inches from a similar pat of the standard cones. Results were recorded in terms of pyrometric cone equivalents (P.C.E.). To record

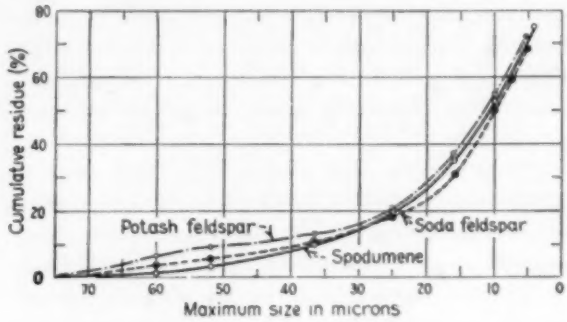

FIG. 1.—Particle-size distribution curves.

results as closely as possible, the down position of the test cones was recorded in terms of the position of the standard cones with respect to a clock face. For example, test cone 1 was in down or 6 o'clock position when standard cone 8 reached 5 o'clock position. In the record of the fusions, this was expressed as test cone $1 = 8^5$.

TABLE II

PYROMETRIC CONE EQUIVALENT OF POINTS ON TRIAXIAL DIAGRAM (FIG. 2)

Point	K feldspar (%)	Na feldspar (%)	Spodumene (%)	P.C.E.	Point	K feldspar (%)	Na feldspar (%)	Spodumene (%)	P.C.E.	Point	K feldspar (%)	Na feldspar (%)	Spodumene (%)	P.C.E.
1	100			8^5	22	80		20	3^3	43	20	40	40	1^3
2	90	10		8^3	23	70	10	20	2^3	44	10	50	40	2^3
3	80	20		7^6	24	60	20	20	1^4	45		60	40	3^3
4	70	30		7^4	25	50	30	20	01^6	46	50		50	4^6
5	60	40		7^2	26	40	40	20	01^4	47	40	10	50	3^6
6	50	50		6^8	27	30	50	20	01^6	48	30	20	50	3^3
7	40	60		6^5	28	20	60	20	1^4	49	20	30	50	3^2
8	30	70		6^4	29	10	70	20	2^4	50	10	40	50	4^2
9	20	80		6^6	30		80	20	3^4	51		50	50	4^6
10	10	90		7^2	31	70		30	2^4	52	40		60	8^3
11		100		7^4	32	60	10	30	1^6	53	30	10	60	8^6
12	90		10	4^6	33	50	20	30	01^6	54	20	20	60	8^3
13	80	10	10	4^4	34	40	30	30	01^5	55	10	30	60	8^2
14	70	20	10	4^2	35	30	40	30	01^5	56		40	60	7^6
15	60	30	10	3^6	36	20	50	30	1^2	57	30		70	10^5
16	50	40	10	3^3	37	10	60	30	1^6	58	20	10	70	11^2
17	40	50	10	3^2	38		70	30	2^5	59	10	20	70	10^6
18	30	60	10	3^3	39	60		40	3^2	60		30	70	10^6
19	20	70	10	3^5	40	50	10	40	2^4	61	25		75	12^4
20	10	80	10	4^2	41	40	20	40	1^5	62		25	75	13^3
21		90	10	5^5	42	30	30	40	1^2					

Table II gives a list of the points on the triaxial diagram tested, their percentage composition, and P.C.E. values. All mixtures that gave erratic results were checked.

To show more clearly the effects of additions of spodumene to feldspar, four curves were plotted showing the relation of P.C.E. to percentage composition. These curves are given in Fig. 3. The

four curves cover potash-soda feldspar, potash feldspar-spodumene, soda feldspar-spodumene, and soda-potash feldspar-spodumene.

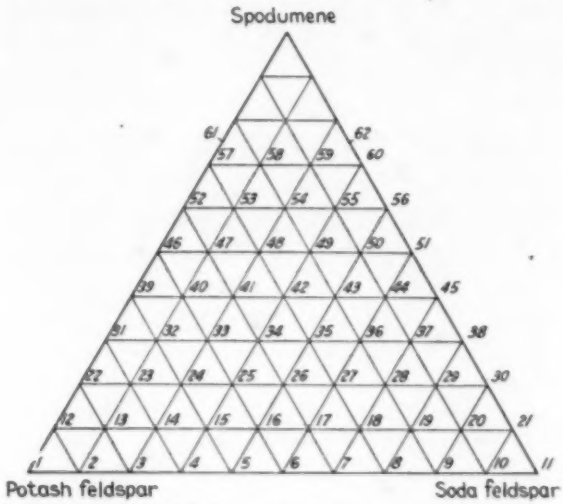

FIG. 2.—Triaxial diagram of ternary system spodumene, potash feldspar, and soda feldspar, showing points tested.

Besides these curves, additional graphic data are shown by the triaxial diagram (Fig. 4) with "contour lines" drawn through points of equal P.C.E. values. As the points investigated were spaced on 10% intervals and as no determinations were made between these points, the location of the lines, or margins between the areas of different cone values, are none too well established. The contours, however, serve to show the approximate areas of equal P.C.E. values and illustrate the rapid changes in fusion properties with changes in composition.

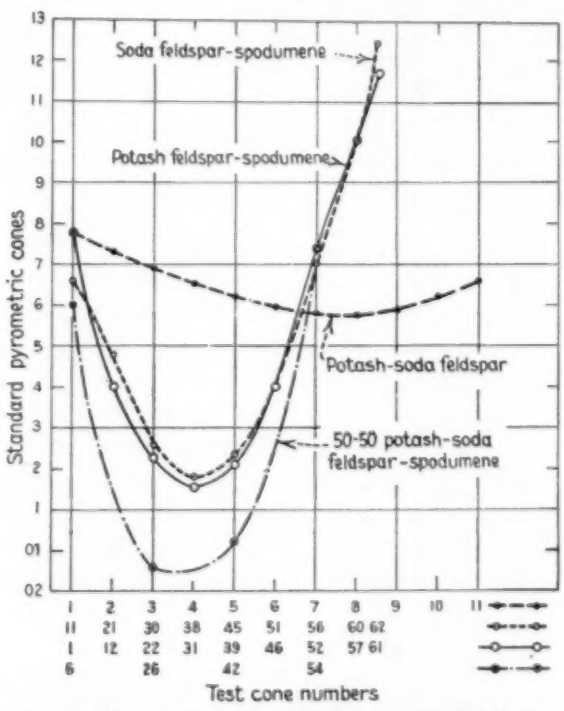

FIG. 3.—Curves showing pyrometric properties of mixtures of feldspars and feldspars with spodumene.

III. Discussion of Results

These results show that additions of 20 to 40% of spodumene to either of the individual feldspars or mixtures of them decrease the P.C.E. several cones.

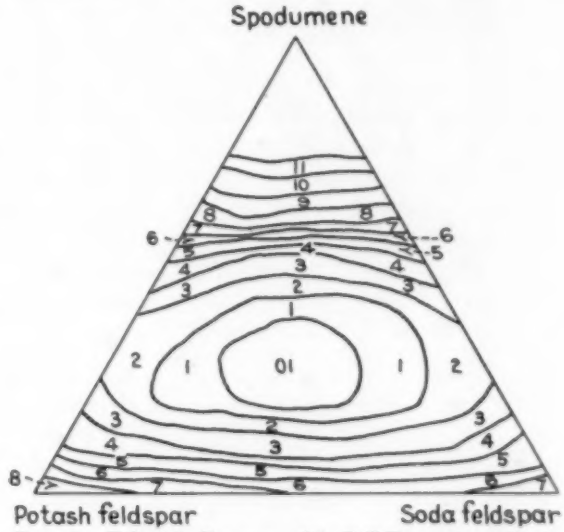

FIG. 4.—Triaxial diagram with P.C.E. contour lines.

As the spodumene is increased above 40%, the P.C.E. of the mixtures increases. The rate of increase in P.C.E. for mixtures with increasing amounts of spodumene above 40% is about equal to the rate of decrease in P.C.E. of mixtures containing from 0 to 20% spodumene.

From the four curves shown in Fig. 3, it can be seen that the mixtures containing spodumene have a much steeper slope than those containing only the feldspars. The solid line curve for the binary system, potash feldspar-spodumene, shows that spodumene additions decrease the P.C.E. more rapidly and to a slightly greater extent than they do in the soda feldspar-spodumene mixtures shown by the dotted line. The dot-dash curve, representing the fifty-fifty blend of the two feldspars, shows that the mixture is affected by the additions of spodumene to a greater extent than either of the feldspars.

The steep slopes and relatively sharp points of the curves indicate the probability of a eutectic point between feldspars and spodumene; the data available, however, are not sufficient to establish this definitely.

The contour lines on the triaxial diagram (Fig. 4) show a considerable area as having P.C.E. values below cone 1. These compare with a P.C.E. of about six to eight for the feldspars and considerably higher for the spodumene.

The area of lowest P.C.E. values has limits of composition approximately as follows:

	Maximum (%)	Minimum (%)
Spodumene	35	15
Potash feldspar	50	25
Soda feldspar	50	20

These limits, expressed in terms of chemical constituents as calculated from the analyses, are as follows:

	Maximum (%)	Minimum (%)
Li_2O	2.5	1.1
K_2O	6.2	3.2
Na_2O	5.1	3.2

These data suggest that spodumene-feldspar mixtures may have considerably more value as fluxes in whiteware bodies and glazes than feldspar alone.

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SOME PYROCHEMICAL PROPERTIES OF PYROPHYLLITE*

By C. W. Parmelee and L. R. Barrett

Abstract

Two samples of pyrophyllite from North Carolina were heated at temperatures from 400° to 1400°C. Studies of weight loss, volume change, and other heat effects were made. X-ray examinations were made of the unheated and heated samples to determine the minerals present.

Pyrophyllite lost its water of constitution between 400° and 700°C without any heat effect or breakdown of the crystal lattice. There was, however, an increased separation of the alumino-silicate layers reflected in a permanent linear expansion. Between 1000° and 1100°C, the dehydrated pyrophyllite decomposed, one of the products being mullite.

In the presence of small quantities of vanadic and tungstic oxides, mullite and cristobalite were noticed at a lower temperature; boric oxide had no effect.

I. Introduction

In the last decade, attention has been given to pyrophyllite as a raw material for the ceramic industries. Shelton,[1] Tailby,[2] Ominin and Popova,[3] Sproat,[4] and Greaves-Walker and associates[5] have investigated its value in ceramic bodies. It seemed desirable, therefore, to obtain information on its fundamental pyrochemical properties. This investigation was designed to elucidate the manner in which pyrophyllite behaves under the action of heat and to identify the products formed as a result of the chemical changes taking place. An attempt was also made to assess the value of some acidic oxides in promoting the formation of mullite.

II. Review of Literature on Pyrophyllite

Pyrophyllite is a hydrated alumino-silicate, similar to talc in appearance. Commercially their differences are not distinguishable, as shown in trade returns.[6] The powdered material finds its chief uses in other industries than in ceramics.

* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 29, 1938 (White Wares Division). Received March 30, 1938.

This paper has been prepared from a thesis written by the junior author to satisfy in part the requirements for the degree of M.S., University of Illinois, and is published with the permission of the Dean of the Graduate School.

[1] G. R. Shelton, "Pyrophyllite, a New Ceramic Raw Material," *Jour. Amer. Ceram. Soc.*, **12** [2] 79–82 (1929).

[2] R. V. Tailby, "Pyrophyllite, a Study of Its Use in Ceramic Bodies," *Ceram. Age*, **21** [1] 4–5 (1933); *Ceram. Abs.*, **12** [4] 163 (1933).

[3] L. V. Ominin and V. T. Popova, "Utilization of Pyrophyllite in Porcelain and Faience," *Keram. i Steklo*, 9 [2] 20–23 (1933); *Ceram. Abs.*, **12** [8] 303 (1933).

[4] I. E. Sproat, "Use of Pyrophyllite in Wall-Tile Bodies," *Jour. Amer. Ceram. Soc.*, **19** [5] 135–42 (1936).

[5] A. F. Greaves-Walker, C. W. Owens, Jr., T. L. Hurst, and R. L. Stone, "Development of Pyrophyllite Refractories and Refractory Cements," *N. C. State College Eng. Expt. Sta. Bull.*, No. 12 (1928).

[6] (*a*) A. H. Emery and B. H. Stoddard, "Talc and Ground Soapstone." Minerals Yearbook, p. 953 (1936).
(*b*) Private communication from the Curator, Geological Museum, London.

The mineral, pyrophyllite, has a wide occurrence. The geology of the pyrophyllite deposits in Moore and Chatham counties in North Carolina has been described by Stuckey.[7] Numerous analyses are to be found in the literature.[8] An analysis of Hemp (North Carolina) pyrophyllite is given by Sproat.[4]

Physical and chemical data on pyrophyllite may be found in the references cited (see footnote references 9 to 22, inclusive).

III. Experimental

(1) Materials

Massive, foliated pyrophyllite from Hemp and Glendon, Moore County, North Carolina, was used. The former was a light greenish gray, talclike substance, containing fine-grained quartz and sericite. The latter was lighter in color with the platy character less well developed. Standard substances for the preparation of X-ray patterns included cryptocrystalline quartz, novaculite, from Alexander County in southern Illinois; cristobalite made by calcining the same quartz with a lime-iron flux at 1400°C for four hours; and mullite from a crucible made by the Champion Spark Plug Company; α- and γ-alumina were prepared from hydrated alumina made by precipitation from aluminum chloride solution with 0.880 ammonia (the α-alumina was ignited at 1330°C and the γ-alumina at 980°C); the cristobalite and mullite were ground in petrol ether in a steel ball mill for 40 hours, the iron being subsequently leached out with dilute hydrochloric acid; the quartz and alumina needed no grinding.

(2) Methods

The pyrophyllite was crushed to pass a 20-mesh sieve and then ground with water in porcelain mills for 40 hours, dewatered, and dried. Disk-shaped specimens, weighing about five grams, were made by pressing the semidry powder at 15,000 lb. per sq. in. The water content, after pressing, was 7% of the dry weight at 110°C. The specimens were fired from 400° to 1400°C, rising in 100°C steps. In all cases, the temperature was raised at a rate of 300°C an hour to the soaking temperature, which was maintained for ten hours or longer. For temperatures up to 1000°C, a nichrome wire-wound electric furnace was employed, to which was connected a temperature regulator that held the soaking temperature to ±5°C. Temperatures above 1000°C were obtained in a box-type gas furnace. In this case, the variation during the soaking period was usually ±10°C. All the temperatures were measured with platinum-platinum rhodium thermocouples. Figure 1 shows the percentage loss in

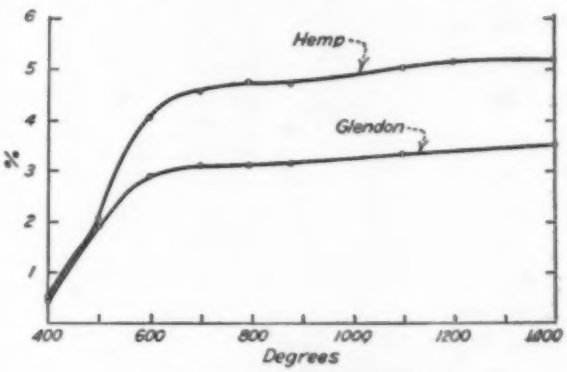

FIG. 1.—Loss of weight on heating.

[7] J. L. Stuckey, "Pyrophyllite Deposits of North Carolina," *N. C. Dept. of Conservation and Development Bull.*, No. 37 (1928).

[8] See especially C. Doelter, Handbuch der Mineralchemie, Vol. 2 (2d part), pp. 120–23. Dresden and Leipzig, 1917.

[9] B. Dammer and O. Tietze, Die Nutzbaren Mineralien, Vol. 2, pp. 376–78. Stuttgart, 1914.

[10] R. Niederleuthner, Unbildsame Rohstoffe Keramischer Massen, p. 235. Vienna, 1928.

[11] J. L. Stuckey, "Dehydration Temperature of Pyrophyllite and Sericite," *Jour. Amer. Ceram. Soc.*, **7** [10] 735–37 (1924).

[12] D. S. Beliankin and A. M. Vinogradova, "Physicochemical Properties of Pyrophyllite," *Trans. Research Inst. Ceram.* [Leningrad], **43**, 1–9 (1934); *Ceram. Abs.*, **14** [10] 258 (1935).

[13] E. Thilo and H. Schunemann, "Chemical Studies of Silicates: IV, Behavior of Pyrophyllite, $Al_2(Si_4O_{10})(OH)_2$, on Heating and the Existence of a 'Water-Free Pyrophyllite,' $Al_2(Si_4O_{10})O$," *Z. anorg. allgem. Chem.*, **230** [4] 321–35 (1937); *Ceram. Abs.*, **16** [10] 311 (1937).

[14] V. T. Nakai and Y. Fukami, "X-Ray Examination of Ceramic Raw Materials: V," *Jour. Soc. Chem. Ind.* [Japan], **36** [11] 604–606*B* (1933); *Ceram. Abs.*, **13** [3] 72 (1934).

[15] H. S. Houldsworth and J. W. Cobb, "Behavior of Fire Clays, Bauxites, etc., on Heating," *Trans. Ceram. Soc.* [Eng.], **22** [2] 111–37 (1922–23); *Ceram. Abs.*, **3** [2] 48 (1924).

[16] M. A. Jourdain, "Studies of Constituents of Refractory Clays by Means of Thermal Analysis," *Céramique*, **40** [593] 135–41 (1937); *Ceram. Abs.*, **16** [11] 357 (1937).

[17] K. A. Vesterberg, "Kaolin: (1) Thermal Changes, (2) Rational Analysis of Clays," *Ark. Kemi. Min. Geol.*, **9** 1–26 (1925); *Ceram. Abs.*, **5** [3] 101 (1926).

[18] A. F. Greaves-Walker and C. W. Owens, Jr., "Expansion of Pyrophyllite," *Bull. Amer. Ceram. Soc.*, **15** [9] 303–305 (1936).

[19] (*a*) L. Pauling, "Crystal Structure of Micas and Related Minerals," *Proc. Nat. Acad. Sci. U. S.*, **16**, 123 (1930). (*b*) "Structure of the Chlorites," *ibid.*, **16**, 578 (1930).

[20] J. W. Gruner, "Talc and Pyrophyllite Crystal Structure," *Z. Krist.*, **88** [5–6] 412–19 (1934); *Ceram. Abs.*, **14** [2] 50 (1935).

[21] U. Hofmann, K. Endell, and D. Wilm, "Crystal Structure and Swelling of Montmorillonite," *Z. Krist.*, **86** [5–6] 340–48 (1933); *Ceram. Abs.*, **14** [4] 100 (1935).

weight plotted as a function of the firing temperature.

The change in diameter of the fired disk-shaped specimens was measured by a simple device that is used to measure veritas rings, as well as by calipering.

The crystalline compounds present in the fired specimens were identified by comparison of X-ray patterns made by the powder method, using unfiltered copper K-radiation from a Muller-type Philips Metalix tube passing 23 milliamperes at 40 kilovolts. Exposures of 6 to 8 hours were necessary for the heated clays compared with 5 hours for sodium fluoride. A circular camera of 6.38 centimeters radius and a wedge-specimen mounting were used. It was necessary to grind the samples of heated pyrophyllite in an agate mortar only before mounting in the camera, because grain growth does not occur beyond the limits within which sharp lines can be obtained. Positives made from the X-ray photographs of unheated and heated Hemp and Glendon pyrophyllite are shown in Fig. 2 along with those of quartz, mullite, and cristobalite for comparison. The soaking temperatures are added. Table I shows the minerals observed in the samples. "Present" indicates that the minerals showed a well-defined X-ray pattern; "weak" implies that only the chief lines were plainly visible.

Thermal effects were observed by the Le Chatelier differential thermocouple method, using artificial α-alumina, calcined at 1330°C as a reference substance. The samples were contained in two roughly cylindrical platinum capsules, each holding about one gram of powder. The capsules were held by a platinum wire which passed through refractory sleeving and out to a clamping device. To the same sleeving was cemented the insulating sleeving for the differential thermocouple. The arrangement of Smyth and Adams[22] was used for the junctions. Readings of electromotive force generated by the thermocouples were taken at $^1/_2$-, 1-, or 2-minute intervals, using a K-type potentiometer for the temperature of the sample. The thermocouples were standardized against one which was checked at the National Bureau of Standards. For comparison, the thermal effect in heated English china clay was observed. The furnace temperature was raised at a nearly constant rate of 300°C an hour. The results are shown in curves in Fig. 3.

TABLE I

MINERALS INDICATED BY X-RAY EXAMINATION

Material	Firing temp. (°C)	Pyrophyllite	Quartz	Mullite	Cristobalite	Pattern No.
Hemp, N. C.	Unfired	Present	Present	Absent	Absent	2, 3
	600	"	"	"	"	4
	795	"	"	"	"	5
	880	"	"	"	"	6
	1000	Weak	"	"	"	7
	1100	Absent	"	Present	Weak	8
	1200	"	"	"	Present	9
	1300	"	Weak	"	"	10
	1400	"	Absent	"	Absent	11
Glendon, N. C.	Unfired	Present	Present	Absent	Absent	15, 16
	795	"	"	"	"	17
	1000	Weak	"	"	"	18
	1100	Absent	"	Weak	Weak	19
	1200	"	"	"	Present	20
	1300	"	Weak	Present	"	21
	1400	"	"	"	"	22

IV. Results and Discussion

(1) Weight Losses

The range of temperature over which water was lost from Hemp and Glendon pyrophyllite, 400° to 700°C, was almost the same for each. The loss occurred at about 150°C lower than was found by Stuckey,[11] which is sufficiently accounted for by his shorter time of heating. The present data fit closely on the curve given by Thilo and Schunemann,[13] incorporating work by Noll and Vesterberg as well as their own, in which the equilibrium loss of weight on heating coarse and fine pyrophyllite is plotted against soaking temperature.

[22] F. H. Smyth and L. H. Adams, "The System Calcium Oxide-Carbon Dioxide," *Jour. Amer. Chem. Soc.*, **45**, 1167–84 (1923).

(2) Volume Changes

A permanent linear expansion was found on heating the specimens to moderate temperatures. From values of 0.55 and 0.3% linear expansion, respectively, for Hemp and Glendon pyrophyllite disks heated at 400°C for 88 hours, there was a steady rise to 3.5 and 3.2%, respectively, after heating at 795°C for 14 hours, followed by a diminution, so that near 1100° and 1200°C the Hemp and Glendon pyrophyllite did not change in size. Beyond these temperatures, the Hemp pyrophyllite shrank considerably more than the Glendon material and appeared more glassy.

A careful examination of the X-ray patterns of pyrophyllite ignited at temperatures from 600° to 1000°C revealed a shift of the pyrophyllite lines toward the undeflected position, amounting to some tenths of a millimeter when the distance from the fiducial spot was rather more than three centimeters. Patterns made from a mixture of unheated and heated pyrophyllite (600°C) showed a separation of the third order lines of 0.6 millimeter both for Hemp and Glendon pyrophyllite. A simple calculation employing the Bragg equation showed that this separation could arise from an expansion of the lattice layers of between 3 and 4%. The observed expansion at this temperature was 2.9% for Hemp and Glendon pyrophyllite. Thilo and Schunemann[13] draw the conclusion from their patterns that this shift, which they also observed, was due to a change to the talc struc-

FIG. 2.—X-ray patterns: Nos. 2 to 11, Hemp pyrophyllite; Nos. 15 to 22, Glendon pyrophyllite (*Q* = quartz, *M* = mullite, *C* = cristobalite); Nos. 25 to 29, Hemp pyrophyllite with no addition and additions of boric oxide (*B*), phosphoric oxide (*P*), vanadic oxide (*V*), and tungstic oxide (*W*), respectively; Nos. 30 to 34, Glendon pyrophyllite with the same additions.

ture. Gruner[20] finds 18.81Å for c_0 for talc and 18.55Å for the corresponding dimension of the pyrophyllite unit cell, so that the conclusion of Thilo and Schunemann is consistent with an expansion of the lattice.

(3) Thermal Effects

Thermal effects measured with a differential thermocouple were small. Both materials showed small but definite heat effects of the same character and at the same temperature as English china clay, but smaller in degree. Taken in conjunction with the observation of kaolinite in the

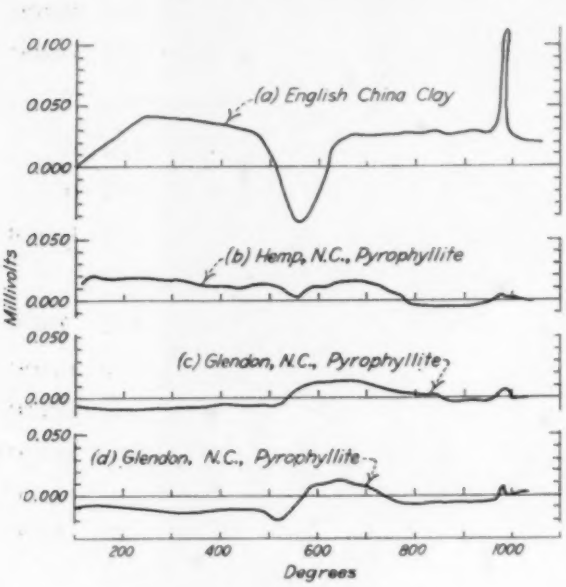

FIG. 3.—Differential thermal curves.

X-ray photograph of unheated, unground Hemp pyrophyllite, the presence of kaolinite in this material in quantities of the order of 10% can be inferred. The lack of a pronounced endothermic effect indicated that dehydration was associated with little or no withdrawal of heat as found in kaolinite. With less certainty, it may be concluded that dehydration does not occur at one particular temperature as it does in talc.[23]

(4) X-Ray Examination

Both kinds of pyrophyllite showed quartz as an impurity, there being more of this in the Glendon material, and the Hemp pyrophyllite showed, in addition, kaolinite and sericite. At 600°C, Hemp and Glendon pyrophyllite showed the patterns of pyrophyllite and quartz. At higher temperatures, the following changes were noticed. One already referred to is the expansion of the lattice. The pyrophyllite pattern was unchanged at 880°C, but at 1000°C, the first-order reflection had disappeared. At 1100°C, all trace of the pyrophyllite had gone, giving place to mullite and cristobalite. At 1200°C, the two latter were stronger. At this point, the Hemp pyrophyllite showed mullite more strongly than cristobalite, while the reverse was true of the Glendon material. The latter contained more quartz initially, which may be ascribed to the preponderance of cristobalite. At 1200°C, quartz was less noticeable; at 1300°C, the last traces were seen. In the pattern given by Hemp pyrophyllite at 1400°C, no cristobalite could be seen.

The patterns reproduced show the persistence of pyrophyllite up to 1000°C. The formation of mullite at higher temperatures and the change from quartz to cristobalite at 1200°C in Glendon pyrophyllite are clearly seen.

(5) Use of Accelerators

Included with the specimens fired at 1000°C and higher were others, made from both Hemp and Glendon pyrophyllite, containing one of the following oxides: boric, phosphoric, vanadic, or tungstic. The first three were added in the proportions of 5 mol.% and the last, $2^1/_2$ mol.%. The weight percentages were, respectively, 0.97, 1.97, 2.52, and 3.20. X-ray patterns (Nos. 25 to 34 in Fig. 2) are those of Hemp and Glendon pyrophyllite with these admixtures after heating at 1000°C for twelve hours.

These oxides increased the glassy nature of the specimens at corresponding temperatures and augmented the firing shrinkage.

The X-ray examination revealed that at 1000°C mullite and cristobalite were present in the specimens containing vanadic and tungstic oxides but not in those containing boric oxide. In general, where mullite was not present, the pyrophyllite had persisted. In the Hemp pyrophyllite containing phosphoric oxide, pyrophyllite and mullite were present together, while in the Glendon pyrophyllite specimens with the same accelerator, cristobalite but no mullite was present. The Glendon material always showed more cristobalite than the Hemp pyrophyllite. The conclusion can be drawn that where the accelerating

[23] R. H. Ewell, E. N. Bunting, and R. F. Geller, "Thermal Decomposition of Talc," *Bur. Stand. Jour. Research*, **15** [5] 551–56 (1935); R.P. 848; *Ceram. Abs.*, **15** [2] 76 (1936).

action was noticed it was more pronounced the greater the molecular weight of the oxide. Tungstic oxide was particularly strong. The incorporation of 3.20% of this oxide produced an effect at 1000°C, attained only at 1300°C in its absence.

V. Conclusions

The samples of pyrophyllite contained quartz and a little kaolinite and the two varieties of North Carolina pyrophyllite used in this investigation gave substantially similar results.

As a result of heating these samples, ground and pressed into disks, at temperatures ranging from 400° to 1400°C and maintained for periods varying from 10 to 88 hours, it was observed that most of the water of constitution was lost between 400° and 700°C. The loss of water was associated with a permanent linear expansion, which may be ascribed to the observed increased separation of the alumino-silicate layers. The characteristic X-ray pattern of pyrophyllite was preserved up to 1000°C. Between 1000° and 1100°C, the pyrophyllite structure broke down, giving place to mullite. The presence of free quartz in the raw materials, which inverted to cristobalite on heating, prevented the identification of the form taken by the silica set free by the decomposition of the pyrophyllite. No marked thermal effects were noticed at the decomposition temperatures.

Vanadic and tungstic oxides added in small amounts lowered the temperature of formation of mullite and cristobalite. Boric oxide had no effect, and phosphoric oxide had a variable effect.

Acknowledgments

The authors wish to thank G. L. Clark, Professor of Chemistry, University of Illinois, for providing facilities for the X-ray examination and W. F. Bradley, Illinois Geological Survey, for help in interpreting the patterns. This work was undertaken while the junior author held a Fellowship of the Salters' Institute of Industrial Chemistry of London, England.

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GRAIN SIZE OF WHITEWARE CLAYS AS DETERMINED BY THE ANDREASEN PIPETTE*

By George A. Loomis

Abstract

The Andreasen pipette method of determining grain sizes by sedimentation is a refinement of the ordinary pipette method. The apparatus was selected for the determination of grain size in a general study of clay casting slips after consideration of other methods. It permits precise results but requires more time and precision than some other methods. Graphs are presented for comparison of typical American kaolins and ball clays and English china clays and ball clays.

I. Introduction

The Andreasen pipette apparatus was chosen for use in this study after consideration of the various types of apparatus which have been used for the determination of subsieve grain sizes. In considering the other types of apparatus, a review of the literature was made. Except in one instance, comparative tests were not made to determine the relative merits of different methods of determining grain size.

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II. Consideration of Other Methods of Grain-Size Determination

(1) Elutriation

Schurecht[1] obtained good results with an improved Schulz elutriating apparatus.

(2) Ordinary Pipette Method

This method was suggested by Robinson.[2] The pipette method has been used to a considerable extent in soils laboratories and elsewhere when

[1] H. G. Schurecht, "Elutriation Tests on American Kaolins," *Jour. Amer. Ceram. Soc.*, **3**, 355 (1920).

[2] G. W. Robinson, "New Method for Mechanical Analysis of Soils and Other Dispersions," *Jour. Agric. Sci.*, **12**, 306–21 (1922).

accuracy is of primary importance. Its greater accuracy, compared with other methods, is so generally recognized that it has been employed as a standard in evaluating grain-size determinations by other methods.

FIG. 1.

Steele and Bradfield[3] and Bray[4] used the pipette for grain-size determinations down to 2 microns and a combination of the pipette and centrifuge for determinations down to 0.0625 micron. The centrifuge was employed to accelerate the test; separations by gravity below 0.5 micron are not practical because of the time required and because Stokes' law becomes inoperative.

(3) Hydrometer Method

This method has been used to a considerable extent for the past ten years by soil chemists. The hydrometer is employed to determine the quantity of material remaining in suspension.

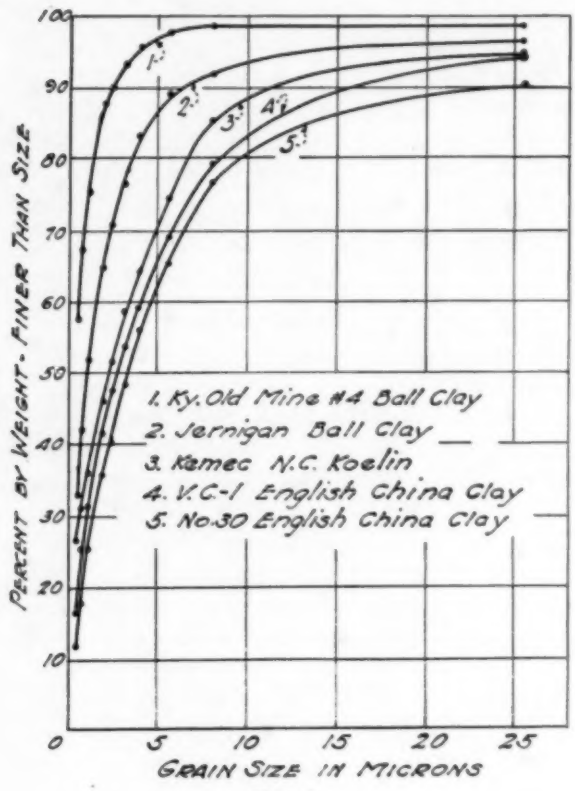

FIG. 2.

It is usually calibrated to read directly in grams of soil per liter of suspension; the Bouyoucos hydrometer[5] is this type.

(4) Kelly Tube Method

This method appeared so promising that a sedimentation tube was made according to

[3] J. G. Steele and R. Bradfield, "Size Distribution in the Clay Fraction," *Rept. 14th Ann. Meeting, Amer. Soil Survey Assn. Bull.*, No. 15, pp. 88–93 (1934); *Ceram. Abs.*, **14** [1] 21 (1935).

[4] R. H. Bray, "Significance of Particle Size within the Clay Fraction," *Jour. Amer. Ceram. Soc.*, **20** [8] 257–61 (1937).

[5] (*a*) G. J. Bouyoucos, "The Hydrometer as a New and Rapid Method for Determining Colloidal Content of Soils," *Soil Sci.*, **23**, 319–30 (1927).

(*b*) G. J. Bouyoucos, "Hydrometer Method for Making Mechanical Analysis of Soils," *Bull. Amer. Ceram. Soc.*, **14** [8] 259–62 (1935).

Kelly's[6] specifications and was used by the author in several trial determinations of grain size in the present investigation before adopting the Andreasen apparatus.

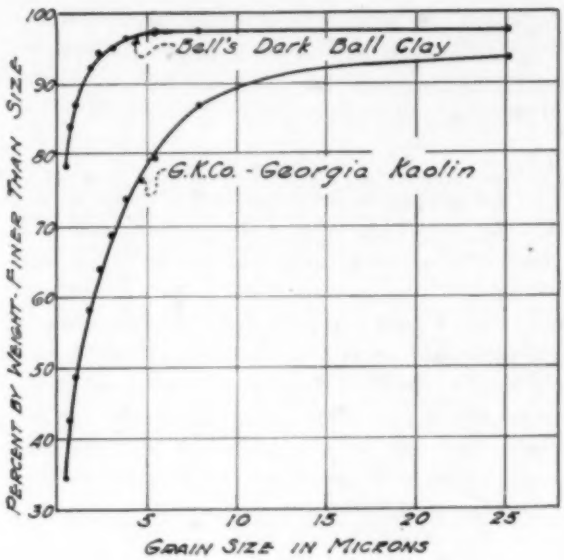

FIG. 3.

Several difficulties were encountered which prevented obtaining consistent results; these were as follows: (1) with relatively coarse suspensions, the coarser particles settled out while pouring the suspension into the tube; it was not possible to homogenize the suspension after filling the apparatus without affecting the clear water

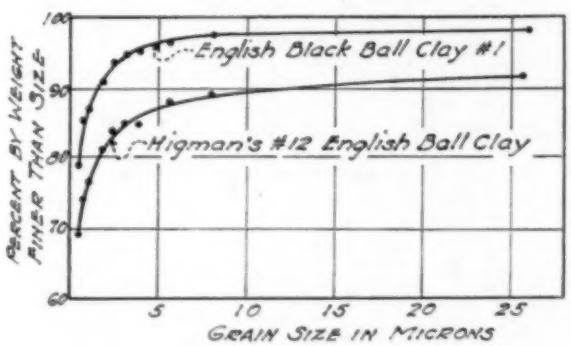

FIG. 4.

in the side tube; (2) during the test, colloidal particles tended to diffuse into the side tube containing the clear water; and (3) readings of the meniscus in the capillary tube were affected by very slight changes in temperature.

Difficulties (1) and (2) probably could have been overcome had a stopcock been introduced at the bottom of the side tube instead of at the outer end as specified by Kelly. The third difficulty might have been overcome by immersing the entire apparatus in a constant temperature bath. It was decided, however, even by eliminating the difficulties mentioned, that the possibilities for undetected errors were greater with this apparatus than by a method, such as the pipette, which permits direct determinations of the percentages by weight.

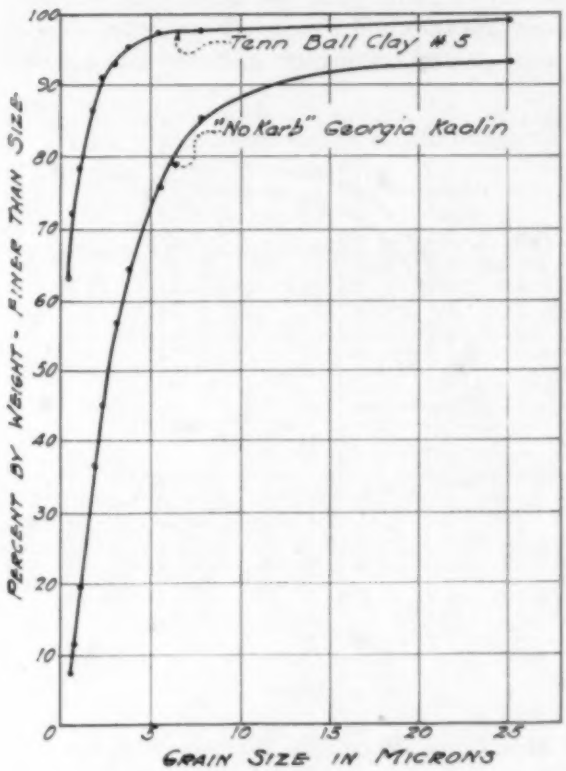

FIG. 5.

(5) Wagner Turbidimeter

This apparatus[7] was designed primarily for grain-size determinations of Portland cement, but it is now being used for various other materials.

[6] W. J. Kelly, "Determination of Distribution of Particle Size," *Ind. Eng. Chem.*, **16**, 928 (1924).

[7] L. A. Wagner, "Rapid Method for the Determination of the Specific Surface of Portland Cement," *Proc. Amer. Soc. Testing Materials*, **33** [Part II] 553–70 (1933).

The color of the material being tested affects the light transmission and, therefore, the results obtained. This, combined with the fact that it is necessary to have a burette calibrated for each type of material tested, led to a decision not to use the turbidimeter, although it appears to have some decided advantages over other methods.

III. Description of Andreasen Pipette

The Andreasen sedimentation apparatus constitutes a refinement of the ordinary pipette method of particle-size determination. The apparatus is shown in Fig. 1. It consists of a glass vessel about 6 centimeters in diameter and it has

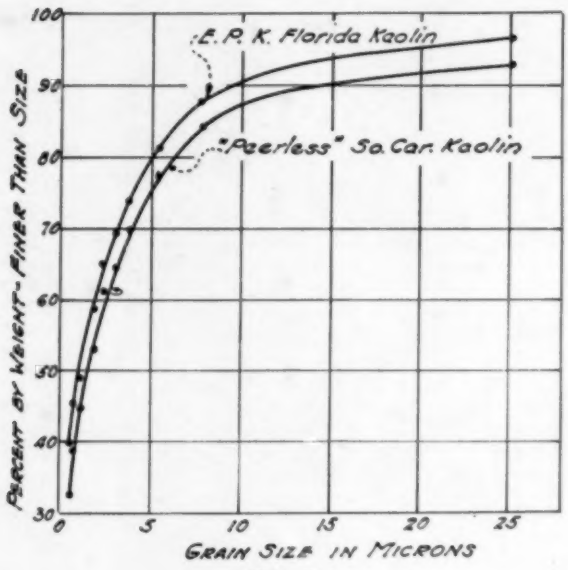

FIG. 6.

a capacity of 550 cubic centimeters when filled to the upper mark on the scale. It is provided with a ground-glass stopper through which passes the stem of a pipette, which extends 20 cm. beneath the surface of the suspension and about 4 cm. from the bottom, the tip being at the level of the zero mark on the scale while the original surface of the suspension is at the 20-cm. mark. The pipette has a capacity of 10 cc., and it is provided with a three-way stopcock and spout for drainage into a weighed evaporating dish or beaker. The chief advantage of the Andreasen apparatus over the ordinary pipette method is that it is self-contained as a unit with the pipette in a fixed position throughout the test. Filling the apparatus to the upper mark and placing the stopper in position automatically brings the pipette tip exactly 20 cm. below the surface. There is no need to remove and replace the pipette (and thereby disturb the suspension) in taking a sample.

The Andreasen apparatus is not practical for separations by gravity below 0.5 micron because of the time required and because Stokes' law becomes inoperative. For the purpose of the present investigation, however, it was not considered necessary to fractionate below this size.

IV. Procedure in Test

In any grain-size determination, it is important that the sample be as completely dispersed as is reasonably possible. Several methods of dispersing the sample have been proposed, some of which are rather involved and time-consuming.[8] Even these, however, are not certain of producing absolutely complete dispersion. It would seem, therefore, that a method which gives reproducible results, with as high a degree of dispersion as possible and without requiring too much time, should be employed for these tests.

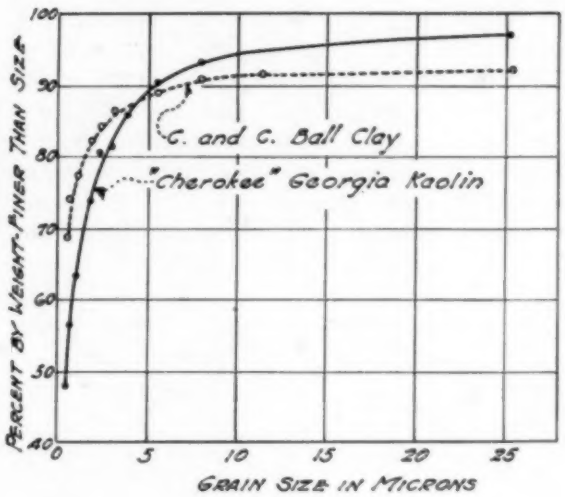

FIG. 7.

Vinther and Lasson[9] made a thorough study of various means of dispersing clay samples before testing in the Andreasen pipette. They tried a wide range of electrolytes and found that sodium pyrophosphate ($Na_4P_2O_7 \cdot 10H_2O$) produced the most complete dispersion of anything tried. They adopted a standard procedure for preparing

[8] See footnote references 3 and 4.

[9] E. H. Vinther and M. L. Lasson, "Grain-Size Measurements of Kaolins and Clays," *Ber. deut. keram. Ges.*, **14** [7] 259–79 (1933); *Ceram. Abs.*, **12** [12] 434 (1933).

samples which was used in the present investigation with only slight modification, inasmuch as it permitted close checks in results on duplicate samples.

The clay sample was crushed to pass a 4-mesh sieve. After determining the moisture content by drying a portion of the sample at 110°C, 5.50 grams (calculated, dry basis) were placed in a

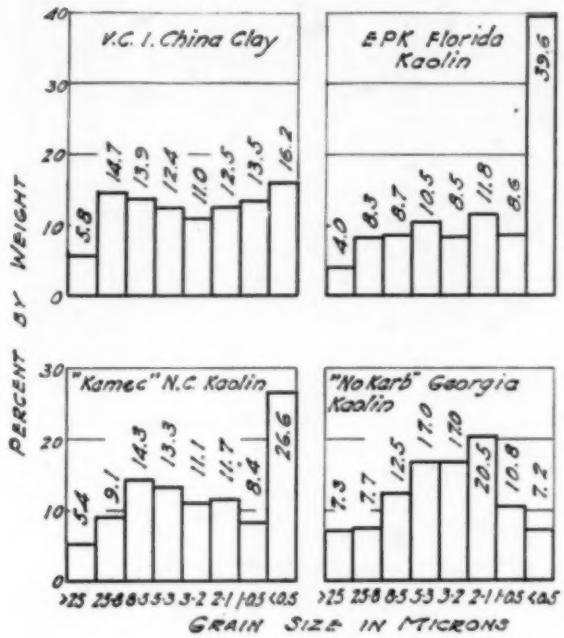

FIG. 8.

250-cu.cm. wide-mouth bottle, to which was added 200 cc. of distilled water. The bottle with the water and sample was allowed to stand for 24 hours; 10 cc. of a solution of sodium pyrophosphate, made by dissolving 24.55 g. in 500 cc. of distilled water, were then added. The bottle with its contents was agitated by rotating end-over-end for 17 hours. This was done by packing the bottle in the jar of a ball mill so as to turn end-over-end as the mill rotated. This is the same procedure as that adopted by Vinther and Lasson, except that they did not let the sample soak in water before agitation and did not state how finely the sample was crushed before dispersing. It was found that extending the time of agitation to $22^1/_2$ and 48 hours did not produce greater dispersion than was obtained in 17 hours; the 17-hour agitation time was therefore adopted.

The dispersed sample was transferred to the sedimentation vessel to which distilled water was added to bring the level of the suspension to the upper mark on the scale, making a total volume of 550 cc. This produced a 1% suspension, and the concentration of the electrolyte was 0.002 gram-molecule per liter.

The vessel with the suspension was placed in a constant temperature bath (30°C) for 15 to 30 minutes to permit it to attain the temperature of the bath. It was then removed, shaken by hand for two minutes, and immediately replaced in the bath; the exact time that shaking was stopped was noted and the stopper carrying the

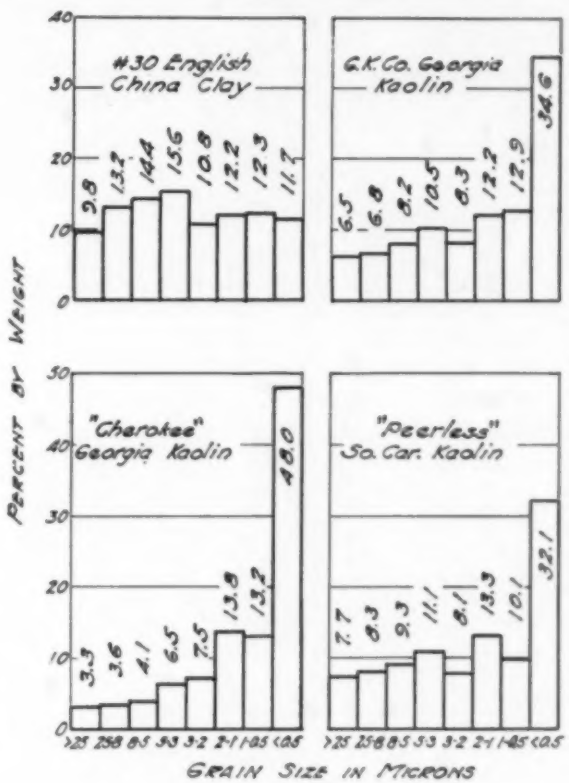

FIG. 9.

pipette was inserted. Samples of 10 cc. were withdrawn at increasing intervals of time, drawing them up at a uniform rate during about 20 seconds. The time intervals for drawing the samples were 3 minutes and 30 minutes; and 1, 2, 3, 5, 8, 24, 48, and 96 hours. These intervals were chosen arbitrarily but were adhered to in order to save time in calculating the grain sizes.

The 10-cc. samples were drained into small weighed beakers, evaporated to dryness at 110°C, and the percentages by weight of the original sample were determined. A correction was made

for the electrolyte in the weight of the dried sample. All weighings were made to 0.1 milligram.

The grain sizes were calculated from Stokes' law according to the falling velocity of the particles, h/t. Each sample drawn has a smaller size of grain than that corresponding to the falling

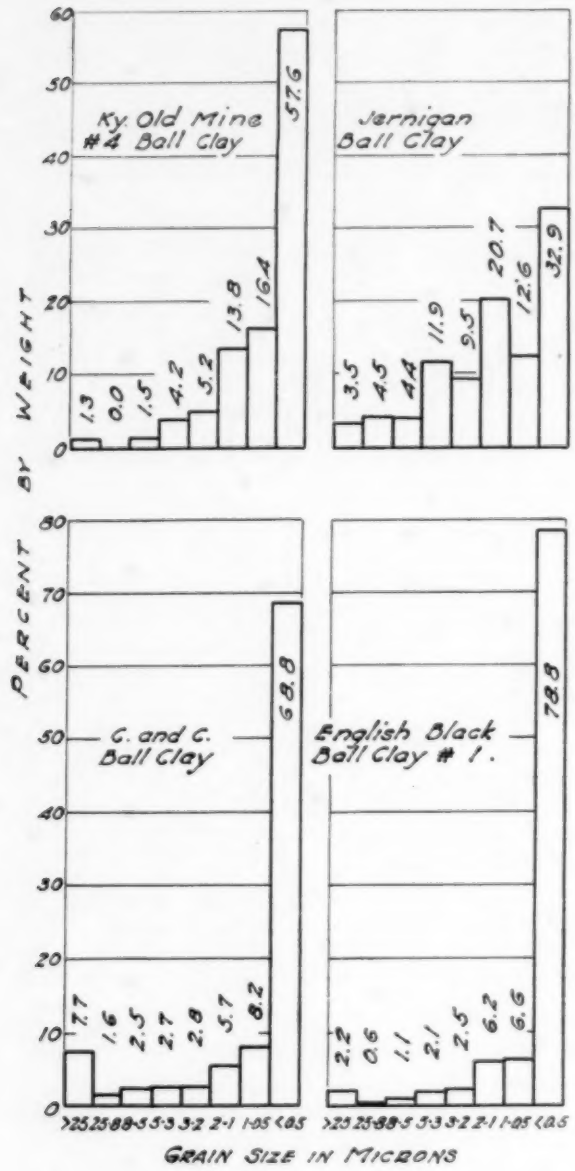
Ky. Old Mine #4 Ball Clay
Jernigan Ball Clay
C. and C. Ball Clay
English Black Ball Clay # 1.
PERCENT BY WEIGHT
GRAIN SIZE IN MICRONS

FIG. 10.

velocity because all particles of large size will have fallen below the level of the pipette tip.

Stokes' law may be expressed as follows:

$$r = \sqrt{\frac{9h\eta}{2(D_1 - D_2)gt}}.$$

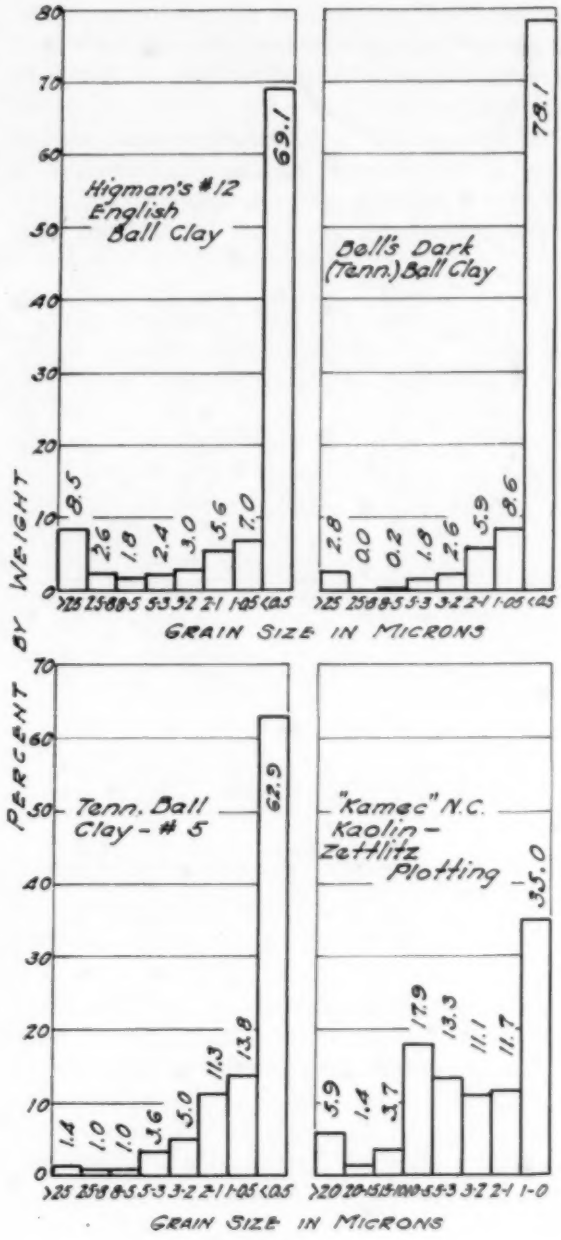
Higman's #12 English Ball Clay
Bell's Dark (Tenn.) Ball Clay
Tenn. Ball Clay - # 5
"Kamec" N.C. Kaolin - Zettlitz Plotting
PERCENT BY WEIGHT
GRAIN SIZE IN MICRONS

FIG. 11.

Where r = radius of spherical particle (cm.).
η = viscosity of suspending medium.
h = distance (cm.) between liquid surface and pipette tip when sample is drawn.
D_1 = true specific gravity of particles.
D_2 = true specific gravity of suspending medium.
g = gravitation constant.
t = time (sec.) from start of test.

When the test is conducted at 30°C on clay with true specific gravity equal to 2.65 and distilled water as the suspending medium,

$r = 6.08\sqrt{\frac{h}{t}}$ (with r in microns; h in cm.; and t in min.).

Andreasen[10] found that Stokes' law could be applied to angular or cubical particles of the same weight as spherical particles. By calculating the grain size as the edge length, or width, of a cube of the same volume as a sphere of radius, r, his grain sizes conformed to the results of sieve analysis.

$$\text{Width of cube} = 1.612r.$$

This seemed to be a more logical designation of grain size than diameters of spheres and was, therefore, adopted.

Duplicate tests were made on each sample. If the weight percentages did not check within 1%, the test was repeated. In most instances, however, the results were nearly identical.

The results for each clay were plotted in a smooth curve with grain sizes (width of cubes) as abscissae and the percentage by weight finer than the corresponding size as ordinates.

From these basic curves, the grain-size distribution for any desired intervals may be obtained and the results plotted to show this distribution.

V. Results

The original data for fifteen clays, from which the basic curves were plotted, are given in Table I. In this table, the grain sizes, expressed as diameters, are given for comparison with the sizes calculated as widths of cubes, the latter being the size designation employed on all of the graphs presented. The results for three of the clays in this table have different size limits than the remainder; this is caused by their difference in true specific gravity.

TABLE I

Width of cube (μ)	25.30	7.92	5.53	3.87	3.13	2.39	1.88	1.07	0.75	0.52
Diameter (μ)	31.38	9.82	6.86	4.80	3.88	2.96	2.32	1.32	0.92	0.64
	Percentage by weight finer than size									
VC 1 English china clay	94.2	79.4	69.0	58.8	53.6	47.2	41.3	31.2	25.1	16.2
EPK Fla. kaolin	96.0	87.5	81.0	73.5	69.1	64.8	58.5	48.9	45.3	39.6
Kamec N. C. kaolin	94.6	85.4	74.3	64.1	58.6	51.4	45.8	35.9	31.0	26.6
"No Karb" Ga. kaolin	92.7	85.0	75.6	63.9	56.4	44.8	36.4	19.4	11.2	7.2
No. 30 English china clay	90.2	76.9	65.4	55.7	48.2	39.9	35.4	25.0	17.4	11.7
Ga. kaolin (Ga. K. Co.)	93.5	86.9	79.5	73.6	68.8	64.0	58.2	48.9	42.9	34.6
"Cherokee" Ga. kaolin	96.7	93.0	90.2	85.8	81.5	80.4	73.8	63.4	56.5	48.0
"Peerless" S. C. kaolin	92.4	83.8	77.1	69.4	64.1	60.7	52.8	44.3	38.4	32.1
Ky. Old Mine No. 4 ball clay	98.7	98.7	97.7	95.7	93.2	90.2	87.7	75.2	67.2	57.6
Jernigan ball clay	96.5	91.7	88.8	83.0	76.4	70.6	64.9	51.5	41.9	32.9
Bell dark ball clay	97.2	97.2	97.1	96.3	94.9	94.3	92.1	86.8	83.9	78.1
Tenn. No. 5 ball clay	98.6	97.6	97.4	95.3	93.0	91.2	86.5	78.2	72.0	62.9
(Width of cube (μ))	(25.63)	(8.02)	(5.60)	(3.92)	(3.17)	(2.42)	(1.90)	(1.08)	(0.76)	(0.52)
C. and C. ball clay	92.3	90.7	88.5	86.7	86.9	84.3	82.3	77.4	74.2	68.8
Higman's No. 12 English ball clay	91.5	88.9	87.8	84.8	85.1	83.8	81.0	76.5	74.1	69.1
(Width of cube (μ))	(26.0)	(8.14)	(5.68)	(3.98)	(3.22)	(2.46)	(1.93)	(1.10)	(0.77)	(0.53)
English black ball clay No. 1	97.8	97.2	96.3	95.0	94.8	93.6	90.6	86.7	85.1	78.7

The basic curves are shown in Figs. 2 to 7. The grain-size distribution graphs, with the distribution intervals adopted in the present investigation, are shown in Figs. 8 to 11. The distribution intervals used are tentative because there appears to be no standard. Figure 11 also shows the distribution for a clay according to the intervals in another system which is being used.

It is interesting to note that the English china clays, VC 1 and No. 30 (Figs. 8 and 9), noted for their good castability, have a fairly uniform distribution from the coarsest to the finest sizes, no one size predominating. On the other hand, all of the domestic kaolins tested show a predominance of one or another fraction, usually the finest. All of the ball clays show a predominance of the finer sizes, the English ball clays Nos. 1 and 12 being finer than most of the domestic ball clays studied.

[10] A. H. M. Andreasen, "Validity of Stokes' Law for Nonspherical Particles," *Kolloid-Z.*, **48**, 175–79 (1929); *Ceram. Abs.*, **9** [1] 66 (1930).

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January 22, 1938	1712	220	12	530	220	2694
February 18, 1938	1728	217	15	540	220	2720
March 18, 1938	1770	216	10	513	220	2729
April 18, 1938	1635	205	60	527	220	2647
May 19, 1938	1643	208	52	548	220	2671
June 21, 1938	1675	210	49	563	220	2717
July 19, 1938	1687	212	41	573	220	2733
August 19, 1938	1701	214	37	574	220	2746
September 19, 1938	1738	216	37	580	220	2791
October 19, 1938	1780	215	27	577	220	2819

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November, 1938
17—11

Abrasives

Abrasives in cleansers and polishes. M. P. Schester. *Soap*, **14** [4] 21–23, 74 (1938); *Chem. Abs.*, **32**, 6416 (1938).—The microscopic examination of abrasives when making comparisons between competitive products is described.

Abrasives and grinding. Anon. *Mill & Factory*, **22** [6] 517–20 (1938).—The use of modern abrasives and grinding tools together with grades and kinds of abrasives is discussed with particular reference to the automotive industry. D.A.B.

Abrasives and their tests. A. Guilleaume. *Schleif- & Poliertech.*, **15** [4–5] 71–80 (1938).—Natural and artificial abrasives are described. Methods of testing and graphs showing results of investigations are given. F.E.V.

Advantages and uses of oilstones. A. B. Knight. *Mill & Factory*, **22** [3] 75–77 (1938).—The uses and advantages of the oilstone to the machine tool manufacturer and user are stressed. Objectionable burr left by the grinding wheel is removed, and, as a result, the tool has a keener edge, does its work smoothly and rapidly, and lasts longer. Information on the care of the oilstone is given. K. classifies oilstones, both natural and artificial. D.A.B.

Capillarity and surface tenacity of polishing abrasives. H. R. Power. *Products Finishing*, **2** [8] 22–26 (1938).—P. describes two important properties of electrically fused alumina abrasives necessary for the proper performance of polishing wheels. Polishing grains which contain an oil film on their surface are useless because the glue film does not wet them when making a setup wheel for polishing. Abrasive grains not completely wet with the glue film leave their setting in subsequent use; hence their abrasive value is zero. The polisher should check his grains for oil contamination by checking for capillarity; this can be quantitatively measured by noting the rise of water in a glass tube of narrow bore filled with abrasive standing in a trough of water. The abrasive producer sets standard for each grit by this method. Abrasives for grinding wheels can be bonded by a variety of materials, but polishing wheels can be bonded only by the wet glue film. The grain producer, therefore, has developed the surface of the grit so that the glue bond on a special test now shows an adhesion value of 1100 lb./sq. in. as against 457 lb./sq. in. for the older material. The structure of the polishing wheel also shows a revolutionary change, since the new material packs with a cushion effect, giving an open coat on the wheel facing which requires less frequent dressing and gives longer life. Nine illustrations. H.K.R.

Cutting fluids: their use. W. D. Huffman. *Metal Progress*, **33** [6] 584–86 (1938).—H. presents a survey of present practice in the use of cutting fluids, based on a questionnaire. Fluids were classified as emulsifiable oils, sulfurized mineral oil, sulfurized mineral and lard oil, sulfurized lard and mineral oil, mineral and lard oil, mineral oil. There are no apparent limitations to the use of either emulsions or sulfurized oils, for either one is used on the same type of operation in several cases. The factors governing a selection between the two types should be studied, for there is no economic justification for using a sulfurized mineral oil when an emulsion is satisfactory. The questionnaire did not deal with the tools used or the machinability of the metal being cut. See "Metal—," *Ceram. Abs.*, **17** [4] 127 (1938). F.P.P.

Diamond grinding disks of known granulation. A. Meyer. *Schleif- & Poliertech.*, **15** [4–5] 81–85 (1938).—To work hard metal tools, the grinding disks must be manufactured with new diamonds of high quality and controlled granulation. The disks sold under the trade mark Winter and their use are described. F.E.V.

Hydride process: III, Titanium silicides. P. P. Alexander. *Metals & Alloys*, **9** [7] 179–81 (1938).—Titanium silicide has long been known as a material of exceptionally high hardness, but attempts to produce it have resulted in broad variations in hardness, owing to loss of Si or Ti through oxidation by atmospheric O_2. In the hydride process, powdered titanium hydride and powdered Si in molal proportions are mixed, pressed into

briquets, and heated in a vacuum furnace to about 500°C. The vacuum is maintained only until the H_2 starts to evolve; after this, sintering occurs in an atmosphere of constantly evolving H_2 until the combination of Si and Ti is complete. The titanium silicide produced by this process is said to be hard enough, even in spongy form, to cut quartz or tungsten carbide and has good thermal conductivity. F.P.P.

Novelties in abrading machine construction. ANON. *Schleif- & Poliertech.*, **15** [4–5] 86–101 (1938).—The descriptions are based on the machines exhibited at the Leipzig Spring Fair, 1938. 25 illustrations. F.E.V.

Polish on metals. W. COCHRANE. *Proc. Roy. Soc.* [London], **A166,** 228–37 (1938).—In an attempt to clarify the Beilby amorphous layer theory of polishing, electron diffraction patterns formed by transmitted electrons were obtained. C. deduced that the film consists of very small crystal grains and that the atoms in the polish layer of a metal are arranged similarly to the atoms in a monatomic close-packed liquid at a given instant. A.P.

Scrap grinding wheels used as foundry refractories. W. H. SALMON. *Foundry Trade Jour.*, **57,** 427–28 (1937). —Silicon carbide scrap, on account of its high conductivity, is used for making moldable chills for heavy sections. It is crushed or bonded with clay or cement. It is also used with a fusible bond, such as sodium silicate or phosphoric acid, so that a hard facing of the material is cast into the wearing faces of the cast iron or steel articles to extend the working life or to give extra resistance to local abrasion. Rammed linings for melting furnaces are another application of this scrap material. High alumina material from emery wheels and emery scrap is better for mold dressings where certain steels which readily form silicate slags are used. This material is valuable in securing heating elements in electric resistance furnaces owing to its good electrical resistance and refractoriness. A discussion is included. H.E.S.

PREPRINT

Abrasive materials. BERTRAND L. JOHNSON AND A. E. DAVIS. Preprint from U. S. Bur. Mines Minerals Yearbook, 1938. 16 pp. Govt. Printing Office, Washington, D. C. Price 5¢. R.A.H.

PATENTS

Abrading device. FRANK POSTMA. U. S. 2,127,528, Aug. 23, 1938 (Nov. 5, 1937).

Abrasive disks. F. B. DEHN (Stratmore Co.). Brit. 490,287, Aug. 24, 1938 (Feb. 6, 1937).

Abrasive wheel and mounting. EDWARD VAN DER PYL (Norton Co.). U. S. 2,128,213, Aug. 23, 1938 (Feb. 3, 1936).

Apparatus for filing or abrading. L. A. WILKIE. Brit. 489,919, Aug. 17, 1938 (May 27, 1937).

Applying abrading disks to grinding or polishing machines. V. G. SCHWENKE (Briggs Mfg. Co.). U. S. 2,127,703, Aug. 23, 1938 (Nov. 30, 1936).

Bench grinding machines and work piece supporting means therefor. WALKER-TURNER CO., INC. Brit. 489,-733, Aug. 17, 1938 (Oct. 12, 1936).

Boron carbide. COMPAGNIE DES MEULES NORTON (SOC. ANON.). Fr. 822,754, Jan. 7, 1938; *Chem. Abs.*, **32,** 4447 (1938).—An alloy of B_4C and B is made by charging an electric resistance furnace with a mixture of B oxide and C in amounts such that an excess of B over that required to form B_4C is obtained and heating progressively while keeping the temperature below that at which the normal B carbide or B carbide rich in C is formed. The power used is maintained below 240 kw./sq. m. of the surface of the electric resistance. Fr. 822,755. In making B carbide from a granular material partially reduced coming from a preceding treatment in a furnace, the O and B content of the material is determined, and B_2O_3 and C are added in the proportions needed to eliminate the whole of the O as CO and to transform the whole of the B into carbide in the form of an ingot during the progressive heating in an electric resistance furnace.

Coated abrasive article and method of making. N. P. ROBIE (Carborundum Co.). U. S. 2,128,966, Sept. 6, 1938 (Feb. 7, 1935).

Coated abrasive product and method of manufacturing. R. C. BENNER AND R. L. MELTON (Carborundum Co.). U. S. 2,128,905, Sept. 6, 1938 (Feb. 6, 1935).

Crankshaft grinder. U. G. WILLIS. U. S. 2,129,253, Sept. 6, 1938 (July 13, 1936).

Cylinder grinder. J. M. KROHN AND E. H. SIMPSON. U. S. 2,128,751, Aug. 30, 1938 (Nov. 22, 1934).

Device for honing razor blades. E. TAYLOR. Brit. 490,220, Aug. 24, 1938 (Feb. 10, 1937).

Grinding or abrading machines. SOC. GENEVOISE D'INSTRUMENTS DE PHYSIQUE. Brit. 489,818, Aug. 17, 1938 (Nov. 4, 1936).

Grinding machine. H. L. BLOOD (Heald Machine Co.). U. S. 2,127,856, Aug. 23, 1938 (Dec. 21, 1936). G. F. MAGLOTT (Brown and Sharpe Mfg. Co.). U. S. 2,127,877, Aug. 23, 1938 (March 3, 1936). W. A. WEED. U. S. 2,128,762, Aug. 30, 1938 (Aug. 17, 1937).

Grinding wheel. COMPAGNIE DES MEULES NORTON (SOC. ANON.). Fr. 824,597, Feb. 11, 1938; *Chem. Abs.*, **32,** 6022 (1938).—The wheel is made from an abrasive, an organic binder such as a resin or rubber, and a filler composed of an alkali metal salt of an acid containing O, *e.g.*, anhydrated borax, Na_2SO_4, or a phosphate, of melting point below 1200°.

Grinding wheel dressing unit. J. W. PARKER. U. S. 2,127,614, Aug. 23, 1938 (Dec. 5, 1935).

Grinding wheel for glass grinding apparatus. PILKINGTON BROS., LTD. Ger. 660,280, April 28, 1938 (Sept. 20, 1933); XII/67*a*. 15. The grinding wheel is provided with projections and operates on the underside of the work piece. The projections on the grinding wheel are formed by channels arranged obliquely to the radii and in such a manner that the part of the channel lying on the larger end of the radius aids revolving of the wheel; the planes of the sides of these oblique channels are also oblique to the surface of the grindstone planes and so slanted as to aid revolving of the grinding wheel. D.A.B.

Grinding wheel reciprocating mechanism. H. S. INDGE (Norton Co.). U. S. 2,128,675, Aug. 30, 1938 (May 13, 1937).

Grinding wheel truing device for grinding or abrading machines. CHURCHILL MACHINE TOOL CO., LTD., AND H. H. ASBRIDGE. Brit. 489,519, Aug. 10, 1938 (March 31, 1937).

Honing machine. W. P. HUNT AND D. C. EIPPER (Moline Tool Co.). U. S. 2,128,706, Aug. 30, 1938 (Oct. 25, 1937).

Knife-grinding attachment. SAMUEL RUBENSTEIN AND HARRY AMAZON (Meyer Levine). U. S. 2,129,538, Sept. 6, 1938 (Feb. 26, 1936).

Making abrasive-coated material. R. C. BENNER AND R. L. MELTON (Carborundum Co.). U. S. 2,128,907, Sept. 6, 1938 (Oct. 8, 1936).

Manufacture of boron carbides. I. G. FARBENINDUSTRIE AKT.-GES. Brit. 489,563, Aug. 10, 1938 (Jan. 30, 1936).

Manufacturing abrasive articles. OTTO SCHNEIDER. Ger. 660,633, May 5, 1938 (April 17, 1935); IV*c*/39*b*. 4.02. The abrasive is mixed with a resin which can be hardened as a binding agent, and the mixture is pressed to the grinding shape without application of heat and is hardened without pressure. As binding agent, a solution of polymerizing compounds of vinyl or acrylic acids or polymerized styrene in a mixture of a highly boiling aldehyde and a phenol, such as furfural and cresol, or benzaldehyde and a phenol is used. D.A.B.

Method and apparatus for balancing a grinding wheel. A. B. HOLMSTROM AND OSCAR WAHLBERG (Norton Co.). U. S. 2,128,673, Aug. 30, 1938 (Aug. 11, 1937).

Method and means for abrading lenses. K. C. BURROUGHS (Bausch & Lomb Optical Co.). U. S. 2,129,522, Sept. 6, 1938 (Oct. 9, 1935).

Method and means for grinding and polishing sprocket teeth. ERNEST ROSS (United Research Corp.). U. S. 2,129,031, Sept. 6, 1938 (April 24, 1935).

Polishing compound. HYMAN LIBOVITZ, WALTER

MUELLER, AND WILLIAM PFEIFFER (Allegro Co.). U. S. 2,129,377, Sept. 6, 1938 (June 18, 1935).

Producing abrasive or polishing wheels permeated with artificially produced hollow spaces by using artificial resin and abrasive particles. DEUTSCHE GOLD- UND SILBER-SCHEIDEANSTALT VORM. ROESSLER. Ger. 660,986, May 12, 1938 (Nov. 7, 1933); IV*c*/39*b*. 22. A mixture of abrasives and suitable resin which forms a porous mass upon heating or which contains a substance producing gas and is provided with fine openings to allow escaping of air or gas is fabricated in the usual manner by heating. D.A.B.

Producing pure alumina. A. S. BURMAN. Brit. 490,099, Aug. 24, 1938 (Aug. 23, 1937).

Production of flexible abrasive articles. R. C. BENNER AND R. L. MELTON (Carborundum Co.). U. S. 2,128,906, Sept. 6, 1938 (Dec. 20, 1935).

Razor stropping mechanism. D. G. MCPEAK. U. S. 2,129,378, Sept. 6, 1938 (March 27, 1936).

Self-adjusting spindle bearing. S. W. BATH AND H. M. ALLISON (John Bath & Co.). U. S. 2,127,854, Aug. 23, 1938 (April 15, 1936).

Tool-sharpening apparatus. W. H. MCGILL. U. S. 2,128,591, Aug. 30, 1938 (Jan. 3, 1936).

Valve-grinding apparatus. H. G. MILLER. U. S. 2,127,748, Aug. 23, 1938 (June 14, 1934; renewed Dec. 28, 1937).

Art and Archeology

Clayworking a lost art after reign in Italy. ANON. *Stone*, **59** [2] 62–63 (1938).—During the time of Luca della Robbia, Italian terra cotta rose to the highest expression in the art of design. In the hands of the so-called imitators of Michelangelo, the art degenerated and soon lost the standing and admiration which it had once held. P.G.H.

Dresden faience. FRITZ FICHTNER. *Ber. Deut. Keram. Ges.*, **18** [8] 333–42; [9] 393–418 (1937).—F. gives a historical sketch of the production of Dresden faience, from its inception in 1708 to 1784, discussing the ware of workers who were best known during that period. Illustrated. E.J.V.

Laura Anne Fry: originator of atomizing process for application of underglaze color. KENNETH E. SMITH. *Bull. Amer. Ceram. Soc.*, **17** [9] 368–72 (1938).

Medieval heraldry in painted glass. F. S. EDEN. *Jour. Brit. Soc. Master Glass Painters*, **7**, 63–68 (1937–38).—In the 11th and 12th centuries, heraldic devices were used in the ornamentation of the windows of great houses and castles. In the 14th and 15th centuries the art was at its height. E.P.

Stained glass. C. NORRIS. *Jour. Brit. Soc. Master Glass Painters*, **7**, 74–79 (1937–38).—N. continues the history of 12th and 13th Century glass, including grisaille glass. See *Ceram. Abs.*, **17** [7] 249 (1938). E.P.

Underglaze, majolica, and overglaze colors. ANON. *Keram. Rundschau*, **46** [1] 5–7 (1938).—A series of 17 recipes is given. These frits may be produced in a small kiln with conical crucibles. F.E.V.

PATENTS

Decalcomania paper. JOHN MACLAURIN. U. S. 2,128,588, Aug. 30, 1938 (Dec. 11, 1935).

Designs for:

Ashtray. F. R. CASS (Mitchell-Bissell Co.). U. S. 111,173, Sept. 6, 1938 (March 14, 1938).

Bottle. N. F. STEUER (Owens-Illinois Pacific Coast Co.). U. S. 111,091, Aug. 30, 1938 (July 13, 1938). J. W. BICKS (Carr-Lowrey Glass Co.). U. S. 111,169, Sept. 6, 1938 (July 9, 1938).

Combination soap holder and grab rail. J. H. BALMER. U. S. 110,952, Aug. 23, 1938 (Dec. 15, 1937).

Dish. PASCAL L'ANGLAIS (Oneida, Ltd.). U. S. 111,077, Aug. 30, 1938 (June 11, 1938).

Cements

Effect of glass content on heat of hydration of Portland cement. WILLIAM LERCH. *Jour. Research Nat. Bur. Standards*, **21** [2] 235–40 (1938); R.P. 1127. Price 10¢.—The heat of hydration was determined, by the heat of solution method, for Portland cements prepared from clinker which had been subjected to heat treatments to produce different glass contents. The results indicate that, when different cements are ground to about the same degree of fineness, the quantity of heat evolved between 7 and 28 days will be dependent on a number of factors, the most important being (1) the composition of the cement and (2) the glass content of the clinker. The glass content influences the heat of hydration not only directly but also indirectly through its effect upon the true compound composition. No consistent relation was observed between the glass content and the quantity of heat evolved at 3 days. At 7 and 28 days the quantity of heat evolved for any given composition increased consistently with increasing glass content. K. gives reasons to explain why the difference in glass content, together with the changed compound composition resulting therefrom, may affect the heat of hydration of the cement at various ages. See *Ceram. Abs.*, **17** [4] 131 (1938). R.A.H.

Investigation of the system MgO–water. ROBERT JAGITSCH. *Z. Physik. Chem.*, **A181** [3] 215–20 (1937).—The hydration of MgO was investigated gravimetrically and by Hahn's emanation method. Both methods gave the same results. The hydration takes place in two steps: a rapid surface hydration of approximately 1.4% water, and a slower process which, in the case of MgO obtained by heating magnesium hydroxide to 640°C, in about 430 min. leads to a combination of $MgO \cdot \frac{8}{9}H_2O$. The dehydration temperature to which the magnesium material was first heated to obtain MgO has a great influence upon the speed and the amount of rehydration. A magnesium hydroxide at 640°C, dehydrated, took up in time 40% H_2O. L.E.T.

Talc refuse—talc cement. F. SCHWARZ. *Geol. & Bauwesen*, **8**, 57–61 (1936); *Neues Jahrb. Mineral. Geol.*, Referate II, 487 (1937); *Chem. Abs.*, **32**, 6420 (1938).—Talc, when heated to redness with 15% limestone, forms a cement with hydraulic properties. It can also form artificial stone which is finely porous, light, and nonconducting to heat and which appears likely to be a useful building material.

Enamel

Addition of pigments to enamels (glazes). J. LIEBSCHER. *Zprávy Československ. Keram. Společnosti*, **12**, 113–23 (1935); *Chem. Abs.*, **32**, 4296 (1938).—To fifteen basic enamels were added the following coloring materials: 2% CuO, Sb_2O_3, 10% pink salt, 5% Cr_2O_3, Terrar (ZnO substitute), Fe_2O_3, 2% Cr pigment, 8% TiO_2, 8% SnO_2, 2% RKO, and 4% MnO_2. The coloring effect is reported in tabular form. See "Colors—," *Ceram. Abs.*, **17** [7] 242 (1938).

Adhesion of enamels to iron. J. WHITE. *Foundry*

Trade Jour., **57**, 437–38, 440 (1937).—W. discusses three theories of enamel adherence to iron: (1) Adhesion is the result of mechanical gripping. The presence of metallic dendrites projecting from the metal surface into the enamel layer ensures good adherence. (2) The adhering oxides are oxides of metals which, by virtue of their position in the electromotive series, are displaceable from their compounds by iron and are thus plated out or deposited at the metal surface, giving an intermediate layer to which the enamel adheres (electrolytic theory). (3) A layer of iron oxide is necessary at the interface, this layer being capable of adhering firmly to the metal on one side and the enamel on the other. Cobalt oxide has been suggested to facilitate the formation of this layer. H.E.S.

American developments in enameling furnace practice. ANON. *Foundry Trade Jour.*, **57**, 184–86 (1937).—A review of radiant-tube firing for American vitreous enamel practice is given. H.E.S.

Attempts to determine hardness of enamel. VIELHABER. *Emailwaren-Ind.*, **15** [9] 65–67 (1938).—The resistance to scratches of enamel, determined by means of a diamond, decreases with an increasing addition of opacifier. M.V.C.

Blisters in weld seams. VIELHABER. *Emailwaren-Ind.*, **15** [5] 30–31 (1938).—There are two kinds of blisters: (1) those having a physicomechanical nature and (2) those of a chemical nature. The latter are promoted by sulfur present in the iron. See *Ceram. Abs.*, **14** [1] 4 (1935). M.V.C.

Borax in enamel. VIELHABER. *Emailwaren-Ind.*, **15** [6] 38 (1938).—Cast-iron enamels require up to 10% borax while coat enamels use up to 7%. In both cases boric acid is the only solvent of iron impurities present. See *Ceram. Abs.*, **16** [3] 83 (1937). M.V.C.

Changes in cast iron on enameling. VIELHABER. *Emailwaren-Ind.*, **15** [3] 17–18 (1938).—V. reviews current literature. See *Jour. Amer. Ceram. Soc.*, **21** [1] 24–26 (1938). M.V.C.

Classification of foundry sands. T. R. WALKER. *Foundry Trade Jour.*, **57**, 419–20 (1937).—Classification of foundry sands based on chemical analysis (silica, alumina, and ferric oxide), water content, and mechanical grading based on Boswell classification is recommended. H.E.S.

Control of enameled sheet-iron and cast-iron ware. H. LANG. *Glashütte*, **68** [8] 127–29 (1938).—Tests used to determine the impact strength and resistance to boiling acids and alkalis, weathering, and gases are analyzed. Standards for evaluating enamel qualities are recommended. M.V.C.

Drying enamel ground coats. H. LANG. *Glashütte*, **68** [9] 158–59 (1938).—Rapid drying of the coat prevents the formation of rust spots but promotes the formation of fishscales under certain conditions and lowers adherence. M.V.C.

Elimination of enamel defects. W. O. *Emailwaren-Ind.*, **15** [3] 15–16 (1938).—Causes for the formation of bubbles, blisters, fishscales, copperheads, etc., in enamels are briefly discussed according to the studies of Krynitsky and Harrison (*Jour. Amer. Ceram. Soc.*, **13** [1] 16–61 (1930)), H. Lang (*Ceram. Abs.*, **12** [4] 143 (1933)), and Vielhaber (*ibid.*, **14** [5] 107 (1935)). Patents dealing with the elimination of these defects are mentioned. M.V.C.

Enamels resistant to acids. H. LANG. *Glashütte*, **68** [10] 186–88 (1938).—The assumption that acid-resistant enamels can be obtained only by lowering other enamel properties, such as luster, opacification, melting point, etc., is denied. When dealing with acid-resistant enamels, it must be remembered that alkaline solutions are more or less soluble in water, while the silicates are not; hence, calcite should be used as flux, and the oxides of antimony, cerium, and titanium should be used as opacifiers. The silica content must be between 50 and 52%. Good acid-resistant enamels are obtained by replacing 10% of silica by 10 to 15% TiO_2 and a part of the borax by calcite. L. obtained high-grade acidproof enamels with a melting point of 800° to 850° for sheet iron and 750° for cast iron. Sodium fluosilicate and cryolite should not be used as opacifiers; ceric and antimony oxides are recommended. Fluorspar, especially calcareous fluorspar, should be used as flux. Usual methods of manufacture are used. M.V.C.

Evolution of enameling. W. E. BENTON. *Foundry Trade Jour.*, **57**, 307–10, 366 (1937).—The evolution of enameling from the first crude ornamentation of metal objects is traced through the Italian white enamels of the early 17th Century, by Antoine Neri, and the use of various colors and fluxes. Some of the first enameling in England was in 1750 when Theodore Jansen established a factory at York House, Battersea, for making small toys in white enamel on copper. The first attempts to enamel iron were made by Rinman (on wrought iron) in 1782 and by Hickling (on cast iron) in 1799. The first recipes were based on flint-glass enamels but later were based on pottery glazes. The distinct characteristics are still permanence, brilliance, and purity of color. A discussion is given. H.E.S.

Gray spotted enamels. VIELHABER. *Emailwaren-Ind.*, **14** [51–52] 354–55 (1937).—The compositions of several enamels producing light and dark color effects on the ware are briefly discussed. M.V.C.

Important factors in the pickling of steel. G. WALLQUIST, R. LINDBERG, AND F. W. VON WALTER. *Jernkontorets Ann.; Foundry Trade Jour.*, **57**, 440 (1937).—The results of a research program on the pickling of steels are described. The principal factors which affect the rate of pickling (indicated in the tests as loss in weight per minute in grams per square meter) are the chemical composition and nature of the articles pickled and of the oxide adhering to them, chemical composition and temperature of the pickling bath, stirring of the bath, and the addition of inhibitors. The effect of these factors is discussed. H.E.S.

Inhibitors in pickling for enameling. ANON. *Keram. Rundschau*, **45** [50] 575–76 (1937).—The action of acid on pickled sheet iron evolves nascent hydrogen which diffuses in the steel. The transformation in molecular hydrogen causes defects in enamel: blistering, brittleness, and fishscale. Inhibitors greatly decrease the solubility of iron in acidic baths. The behavior of inhibitors and the rather unsatisfactory, theoretical explanations are given. Inhibitors must be methodically tested before use. Their use in Germany is rather limited. F.E.V.

Magnesia as a constituent of enamel. R. ALDINGER. *Keram. Rundschau*, **46** [9] 93–95 (1938).—Magnesia is seldom used in enameling and only as a suspending agent. Old recipes mention generally a 1 to 4% content. An addition of magnesia in the frit or in the mill increases opacity and melting temperature. The expansion coefficient seems greater than admitted. The influence of magnesia is similar to that of lime. F.E.V.

Mill room and mill-room practice. TRIPLEX FOUNDRY, LTD. *Foundry Trade Jour.*, **57**, 107–108 (1937).—Milling operations used by the Triplex Foundry, Ltd., in manufacturing stoves and grates are illustrated and described. H.E.S.

Mold facings for cast iron and their effect upon vitreous enamel. H. MCNAIR. *Foundry Trade Jour.*, **57**, 448–50, 452 (1937).—The use of carbonaceous facings, such as coal dust, plumbago, Erith, lampblack, etc., results in adsorption of different forms of carbon, with different reactions or oxidation rates during the enameling process; this may account for the differences in pinholing and cohesion of the enamel to the metal. Cracking and chipping are reduced to a minimum with the maximum bond, described as a mechanical bond; this type is more readily obtained by shot blasting. The order of resistance to cracking appeared to be (1) coal-dust facing, (2) patent blacking, (3) lampblacking, (4) wood blacking, and (5) plumbago. H.E.S.

Naturally bonded or synthetic molding sands? A. TIPPER. *Foundry Trade Jour.*, **57**, 492–94, 504–506 (1937).—The advantages of naturally bonded sands are (1) low cost, (2) strict control of mixture not essential,

(3) good surface finish, (4) particular suitability for nonferrous work, and (5) ease of patching of molds. The disadvantages are (1) need of skilled molders, (2) poor permeability, (3) variable molding results, and (4) accumulation of old sand or cost of dumping. The advantages of synthetic sands are (1) ease of molding, (2) regular control, insuring good physical properties, (3) no waste sand to dump, and (4) selected properties of sand to suit the class of work. The disadvantages are (1) difficulty of patching, (2) rapid loss of moisture, and (3) higher cost of sand. H.E.S.

Opacity and solubility of coat enamels as a function of the grain size of opacifier. LUDWIG STUCKERT. *Emailwaren-Ind.*, **15** [9] 63–65 (1938).—Mechanical crushing of technical SnO_2 yields a maximum opacification when ground a short time because of the dispersion of the coarsest aggregates. Particles up to 1μ produce a maximum of opacification; with the decrease in grain size, opacification decreases because of the vitrification of SnO_2 particles. Enamel melts containing SnO_2 fractions of different size show the same solubility with regard to salts or alkalis. The effect of SnO_2 does not depend on the length of its grinding. See "Stannic—," *Ceram. Abs.*, **17** [7] 246 (1938). M.V.C.

Porcelain enameling experiences and developments in Australia and the United States: III–IV. FRED M. BURT. *Products Finishing*, **2** [7] 18–20, 22–29; [8] 28–32 (1938).—Records needed to carry out the revamping of an enameling plant are given in detail. These records give operating executives data for judging performance of personnel, operating costs, production, and shrinkage. B. describes efforts to make good housekeeping an everyday routine in the plant, including systematic placing of equipment and materials and a safety program. To control the standard of quality of the ware, a laboratory was installed. Working standards and specifications were made available for reference and workmen's instructions. A list of magazines that keep executives up to date is given. For Parts I–II see *Ceram. Abs.*, **17** [6] 213 (1938). H.K.R.

Progress in enamel investigation during 1936. C. R. PLATZMANN. *Chem.-Ztg.*, **61**, 977–79, 999–1001 (1937).—The progress in enamel investigation during 1936 is discussed with regard to (1) raw materials, especially the use of calcium, strontium, barium, magnesium, zinc, and antimony salts and borax, and their newly developed uses in enamel manufacture; (2) enamels, their preparation, application, drying, removal, etc.; (3) enamel production, porcelain enamels, colored enamels, and the effects of various treatments; (4) enamel errors during processing; and (5) testing and control methods, the use of the microscope in testing enamels, testing of pickling baths, testing of physical properties of molten enamel, control of color, and determination of the porosity of enamels. 84 references. D.A.B.

Push-and-pull fume removal. CHARLES L. WILLIAMS. *Factory Management & Maintenance*, **96** [7] 76–77, 126, 128 (1938).—W. describes a system by which fumes from acid pickling baths are blown and sucked into fume hoods placed at the side of the pickling tanks. Illustrated. J.L.G.

Red and brown enamels. VIELHABER. *Emailwaren-Ind.*, **15** [5] 29–30 (1938).—Red enamels are obtained by the addition of 8 parts of CdS and 2 parts of Se; 6 to 8% of the pigment is added to the batch. The firing temperature of such enamels is about 850°, due to a high silica content; at lower temperatures the color tone is gray-violet. Red-brown is obtained by additions of 10% of red ferric oxide and 10% quartz. The alkalinity of the enamel is simply determined by treating it with HCl. M.V.C.

Simple determination of opacity. VIELHABER. *Emailwaren-Ind.*, **15** [7–8] 49–50 (1938).—Attempts to determine opacity are discussed. A photometer with a selenium cell is described, and values of opacity obtained with it are analyzed. M.V.C.

System of plant operation to reduce enameling rejects. J. T. GRAY. *Foundry Trade Jour.*, **57**, 13–14, 16, 109–10 (1937).—G. describes incidental tools and equipment used to reduce rejects and control methods in enameling. Illustrated. H.E.S.

Titanium dioxide in the enamel industry. RICHARD ALDINGER. *Glashütte*, **68** [16] 290–91 (1938).—TiO_2 possesses interesting properties for the enameler. Its index of refraction is high (2.6); it is insoluble in water and is not attacked by dilute sulfuric acid and sea salt; it is also nonpoisonous. TiO_2 is not suitable for opacifying because (1) it has a yellowish color tone in the presence of traces of iron which is always present in enamels in some form; and (2) its opacifying effect is not very high, and at least 10% TiO_2 must be used to obtain satisfaction; such high amounts inevitably produce a yellow tint. Attempts were made to counteract this effect by additions of cobalt oxide to neutralize the yellow or by combining it with other opacifiers. TiO_2, however, is useful in acid-resistant enamels. The addition of 3 to 8% of TiO_2 makes enamels acid-resistant without increasing their fusing point. M.V.C.

White opacification of enamel. HEINRICH KIRST. *Glashütte*, **68** [10] 199–201 (1938).—The use of chiolite ($3NaF \cdot 2AlF_3$) for opacification is discussed in detail. Five-valent antimony compounds can be used instead of SnO_2 which has to be imported into Germany. White gas opacification may be obtained with saltpeter, Na_2SiF_2, nitrites, carbonates, formate and acetate salts, naphtol, benzidine, etc. M.V.C.

PATENTS

Apparatus for applying enamel to can bodies. A. L. KRONQUEST (Continental Can Co., Inc.). U. S. 2,129,220, Sept. 6, 1938 (July 6, 1936).

Arrangement for converting a bathtub into vapor bath. H. LUTTERMOLLER. Brit. 490,354, Aug. 24, 1938 (Feb. 21, 1938).

Manufacture of enamel. I. KREIDL. Fr. 830,021, Aug. 25, 1937; *Chem.-Ztg.*, **62** [58] 529 (1938). D.A.B.

Sink. V. J. GRAF (Briggs Mfg. Co.). U. S. 2,127,559, Aug. 23, 1938 (July 27, 1936).

Glass

Availability of optical glass in America. GEORGE W. MOREY. *Jour. Optical Soc. Amer.*, **28**, 5–8 (1938).—Optical glass is manufactured in the U. S. by only one company, but that company manufactures a wide range of glass types and could produce any additional types for which a demand might develop. Disks for reflecting telescopes are not made of optical glass. Manufacture of reflector disks of the largest size has been put on a production basis. The characteristics of optical glass are explained. A.P.

Computation of the strength of windows. A. F. DUFTON. *Phil. Mag.*, **22** [151] 1165–67 (1936).—Specimens of sheet glass and plate glass were broken, and the moduli of rupture were plotted on *permille* paper. D. shows that if the moduli are taken as 4000 lb./in.^{2} and 2000 lb./in.^{2}, respectively, the risk of failure in each case is 1%. On this basis a nomogram is drawn for a pressure of 15 lb./ft.^{2}. This nomogram gives the glazing sizes, for 1% risk, as a function of breadth, ratio of length to breadth, and glass thickness. The formula used is that of Marcus. C.J.P.

Determination of the absorption coefficients of the lithium-beryllium-boron glass "Hetan" in the infra-red region of the spectrum. G. RUDENKO AND S. HERTSRIKEN. *Mém. Phys. Ukrain.*, **4**, 87–90 (1935); *Chem. Abs.*, **32**, 4293 (1938).—The absorption coefficients of the

glass were determined in the region between 0.8 and 2.5μ. The absorption begins to be considerable at 1.6μ. The absorption coefficient increases sharply beyond this wavelength and is much greater than that for ordinary silicate glasses. The value of the absorption coefficient varies greatly with the chemical composition of the glass and increases for all wave-lengths with increase in the ratio $Li_2B_4O_7$:BeB_4O_7. See "Physical—," *Ceram. Abs.*, **16** [1] 14 (1937).

Effect of glass color on setting rates in manufacture of glass bottles. O. G. Burch and C. L. Babcock. *Jour. Amer. Ceram. Soc.*, **21** [10] 345–51 (1938).

Effect of light filters, particularly of neodymium-containing glasses on the seeing of colors. W. Ströble. *Mitt. Opt. Inst. Tech. Hochschule Berlin*, **1937**; abstracted in *Physik. Ber.*, **19** [12] 1266 (1938).—Possibilities of improving the seeing of colors by light filters are theoretically and practically investigated. Theoretically, it must be expected that a filter with the absorption band near the intersection of the red and green basic sensation curve will effect an increase in saturation of practically all colors of average saturation, and an optimum of improvement is obtained by an absorption band at 573 mμ. Such condition is approached by neodymium-containing filters with additional blue absorption. Theoretical and experimental results of tests with Neophane glasses agreed quantitatively. Whitish and very strongly saturated colors, however, can not be changed by any filter. M.H.

Electrical conductivity of thin metallic films: II, Cesium and potassium on Pyrex brand glass surfaces. E. T. S. Appleyard and A. C. B. Lovell. *Proc. Roy. Soc.* [London], **A158** [895] 7–18, 28 (1937).—The method for measuring the resistivity of thin films of rubidium on clean substrates in very high vacua has been extended to cesium and potassium. Conductivity has been observed with cesium films only 0.3Å thick. The decay of conductivity normally shown by these films after cessation of the deposition decreases in the order potassium, rubidium, cesium. The resistivities of the stable films show excellent agreement with the formula previously derived, even with the very thin cesium films. For Part I see *Ceram. Abs.*, **16** [11] 333 (1937). A.P.

Electromotive forces between glass and salts in the melt. Bela v. Lengyel and Anna Sammt. *Z. Physik. Chem.*, **A181** [1] 55–69 (1937).—Measurements were made on the phase-boundary forces existing between glass and alkali ions in lead chloride melts at 550°C. Sodium glass behaves against sodium ions in a concentration of 10^{-4} mol./100 g. $PbCl_2$ as a Na electrode. In pure K glass against a K-ion melt, the potential runs likewise linear with the logarithm of the concentration; the potential difference, however, proves to be smaller than the one calculated according to the Nernst theory. Li chains give Li functions in small concentration ranges. In higher Li^+ concentrations the change of potential is greater than the one found by calculation. An investigation of mixed systems shows that the ion with the smaller atomic weight always takes over the rôle of the potential. A connection exists between the electromotive action and the mobility of the ions in glass. L.E.T.

Glass block for those who work in glass. Anon. *Mill & Factory*, **22** [5] 85 (1938).—The Owens-Illinois Glass Co. uses glass block in the construction of the locker room for its employees. Vacuum characteristics of the block provide insulation against both heat and cold, and it is nontransparent, providing diffused light. Illustrated. D.A.B.

Glass in industrial processes. Anon. *Can. Machinery*, **49** [2] 30–31, 56 (1938).—Glass plays an important part in sugar refineries, chocolate plants, breweries, extract and food factories, and the electrical and building fields. Some of its uses are as follows: reaction kettles, stills, mixers, evaporators, storage tanks, electrical insulators, fiber glass tape, building blocks, grinder guards, insulating wool, and even nuts and bolts. Illustrated. D.A.B.

Glass insulating tapes. Anon. *Chem. Industries*, **42** [5] 549 (1938).—Tapes with the appearance and flexibility of ordinary textiles intended for electrical insulation of motors, generators, transformers, etc., are woven from glass fibers. The high-temperature melting point of the tape far exceeds class B high-temperature insulation. P.G.H.

Glass strains at elevated temperatures. A. J. Monack. *Glass Ind.*, **19** [1] 11–13 (1938).—M. describes a polariscope furnace by means of which samples of glass-metal seals may be examined at 600°; a special cooling arrangement for the Nicol prism is incorporated in the design. With this apparatus, it is possible to determine the temperature at which all strain disappears. Valuable data for annealing conditions and data relating to the intensity and distribution of strains in a given sample over a range of temperature may be obtained. Strain conditions at the temperature of operation of a vacuum tube carrying a tungsten-glass seal are reviewed. E.J.V.

Glass wool. V. M. Bukhman. *Prom. Org. Khim.*, **4**, 617–19 (1937); *Chem. Abs.*, **32**, 6017 (1938).—B. discusses the production and uses of glass wool, chiefly American practices.

Hollow glass decoration. A. Dorn. *Tchéco-Verre*, **4**, 171 (1937).—D. describes two processes of glass painting, needle etching, and spraying. Artistic effects are produced by color-spraying with an Aerograph machine, using stencils for different portions of the pattern. Although the basic principles of glass cutting are unchanged, the introduction of modern wheels and the electric drive has accelerated production and given greater accuracy. E.P.

Important processes for sealing ceramic materials to metal and glass. H. Handrek. *Ber. Deut. Keram. Ges.*, **18** [12] 539–48 (1937).—Joints to metals can be made by riveting, etc., shrinking-on, or soldering to silver films fired to the ceramic material. In describing the theory and practice of sealing ceramic materials to glass, special reference is made to the vacuum-tight joints in thermionic valves and similar apparatus. Illustrated. See "Ceramic-metallic—," *Ceram. Abs.*, **16** [3] 94 (1937). E.J.V.

Influence of rare earths on the ultra-violet light absorption of glass and its color changeability. V. Čtyroký. *Skláfské Rozhledy*, **15**, 94–128 (1938).—To a base glass of the composition SiO_2 69.02, R_2O_3 0.32, CaO 12.99, Na_2O 4.57, and K_2O 13.01%, additions were made of vanadium, chromium, neodymium, cerium, praseodymium, cobalt, and titanium oxides, separately or in conjunction. Ultraviolet transmissions were measured on a quartz spectrograph, transmissions in the visible spectrum being measured by a spectrophotometric method employing a photoelectric photometer system. C. deduced the following rules for the apparent color changeability of glasses colored by the above oxides in different types of illumination:

If a = % effect of sunlight between 4000 and 5550Å on the eyes after passage through the glass,
b = similar % effect of sunlight between 5550 and 7000Å,
c = % effect of electric light between 4000 and 5550 Å on the eyes after passage through the glass, and
d = similar effect of electric light between 5550 and 7000Å,

then change of color in sunlight and electric light arises if a/b is greater than 1 and c/d less than 1. The color change is greater, the larger the difference $a/b - c/d$. Optimum conditions are obtained when $a/b - 1 = 1 - c/d$. If a/b or c/d is greater than 1, the glass color tends to the blue end of the spectrum. With a/b or c/d less than 1 the color tends to the red. Colors produced by combinations of the above oxides and the changes produced in sunlight and electric light are enumerated. E.P.

Infra-red and ultra-violet absorption of glasses. Dependence upon temperature. S. Meyer. *Glastech. Ber.*, **14**, 305–21 (1936).—Rock salt and quartz spectrometers were used in making measurements in the infra-red and ultra-violet, respectively. The apparatus and technique are described in detail. A series of 18 colored and optical glasses were examined. The results are presented graph-

ically. With all glasses there is a broadening of the absorption region with increasing temperature in both the ultra-violet and the infra-red (an effect long known for the visible region), a flattening of the transmission curves, and displacement toward longer wave-lengths. The amount of displacement of band edges and changes in limiting values of the transmission differ for individual glasses. The change in the region of high transmission for the colorless glasses examined was of the same order of magnitude as the accuracy of measurement. Because of spreading of the absorption region in the long wave-length infra-red, a displacement of the steep transmission curve is not noticeable. With the glasses SF11 and FK5 (Jena), with strong absorption bands at 3.1 μ, there was no displacement of these bands, but as a result of flattening of the curves with increasing temperature there are displacements toward shorter wave-lengths of the second transmission maxima amounting to 0.7 mμ/°C and 0.3 mμ/°C for SF11 and FK5, respectively. The first group of colored glasses, red and yellow, differ essentially only from the colorless glasses in that the absorption edge, which is in the ultra-violet for the clear glasses, is displaced to the visible region (with glass RG7, to the infra-red). The transmission maxima for the red glasses are not changed, but the yellow glasses show a slight increase with increased temperatures. The second group of glasses, green and blue, have no broad region of maximum transmission, but, owing to absorption bands, several regions of transmission are formed. The maximum values decrease with increasing temperature, and the absorption bands are displaced toward longer wave-lengths. The transmission maxima decrease and the minima increase. Transmission changes with temperature are shown to be reversible with no observable hysteresis effects. The total radiation transmitted by RG7 glass from a radiator at 2087°K in going from 20° to 395°C was decreased 16.5%. For VG3 going from 20° to 435°C, the decrease was 13.7% with the radiator at 2133°K. The yield of biologically active radiation from a tungsten and mercury lamp through Uviol M glass decreased 47 and 46%, respectively, in going from 26° to 425°C. 21 references. J.F.H.

International Glass Congress, July 6 to 15, 1939. ANON. *Bull. Amer. Ceram. Soc.*, **17** [9] 381 (1938).

Layout of a small mirror silvering shop. G. SCHIEB. *Oesterr. Glaserztg.*, **3**, 25–29 (1938). J.F.H.

Lithium in glass and ceramics. E. PRESTON. *Foote-Prints*, **11**, 1–15 (1938).—The technology of lithium and its compounds is outlined. 27 references. A.P.

Measurement of surface tension of viscous liquids. C. A. BRADLEY, JR. *Jour. Amer. Ceram. Soc.*, **21** [10] 339–44 (1938).

Optical glass at the National Bureau of Standards. A. N. FINN. *Jour. Optical Soc. Amer.*, **28**, 13–17 (1938). A.P.

Optical glass requirements of the optical industry. W. B. RAYTON. *Jour. Optical Soc. Amer.*, **28**, 8–12 (1938).—The variety of optical constants available is great, but the designer is in need of combinations of index of refraction and dispersion not now available. A.P.

Optical glasses. OSZKÁR KNAPP. *Technikai Kurir*, **9**, 44–46 (1938); *Chem. Abs.*, **32**, 6017 (1938).—The systems of nomenclature of various factories are described, the 19 classes of optical glass of the Jena factory and their chemical composition are shown, and the industrial uses of the 115 types of optical glasses manufactured throughout the world are discussed.

Optics and the glass industry. E. D. TILLYER. *Jour. Optical Soc. Amer.*, **28**, 1–4 (1938).—Optical and ophthalmological glasses together use less than 0.1% of the total annual tonnage of glass, but they require very special properties: varied refractive index-dispersion ratios, stability to light and atmosphere, controlled thermal expansion, high freedom from bubbles, and specific light absorptions. Recent findings indicate the beginning of a new era in materials to design a refracting system. Phosphate and borate glasses have been stabilized, and remarkable new properties have been discovered. Minor amounts of certain elements produce great changes in properties. Very high index glasses have been obtained with some of the rarer elements. A remarkable set of properties, including softening temperatures as low as 160°C, have been discovered for glasses based on beryllium fluoride. A.P.

Production of selenium ruby glass in multipot furnaces. S. M. BREKHOVSKIKH. *Keram. & Steklo*, **14** [4] 15–17 (1938).—Selenium ruby glass of different color tones may be manufactured in multipot furnaces under normal temperatures and atmosphere. The required color tone may be obtained by using corresponding conditions of melting, change in chemical composition, and pigments. Selenium burns out chiefly in the first period of melting; the temperature should not be over 1430°. Little selenium is volatilized during purifying. The glass should not foam. M.V.C.

Rock wool industry grows in Canada. ANON. *Stone*, **59** [2] 62 (1938).—Five plants using limestone as the raw material, with a total capacity of 50 tons daily, are in operation, and the erection of several others is proposed. P.G.H.

Safety plate glass production. ANON. *Mill & Factory*, **22** [6] 254 (1938).—The production of safety plate glass, from the furnace to the installed glass, is described and illustrated. D.A.B.

Sheet glass permeable to ultra-violet rays. OSCAR KNAPP. *Glashütte*, **68** [10] 202–204 (1938).—Ordinary sheet glasses transmit less then 1% of the ultra-violet rays at 302μ; at 320μ they transmit from 5 to 20%. Sheet glass designated as permeable to ultra-violet rays should possess a 50% transmission at least at 302μ. M.V.C.

Telescope mirrors. H. J. MEERKAMP VAN EMBDEN. *Phillips Tech. Rev.*, **1** [12] 358–62 (1936).—The degree of precision to which the surface of mirrors must conform to the true shape for use in large reflecting telescopes is exceptionally high. Deviations from the true shape occur owing to sag, bending under its own weight, and small temperature changes in the upper and lower surfaces of the glass disk. The process described is one whereby the advantages of metal and glass mirrors are combined in a casting of chrome iron, the back of which is a ribbed construction and the surface of which is plain. This metal has the same coefficient of expansion as the glass to be used. The top of the chrome-iron casting is machined to conform roughly to the final surface contour of the mirror. A glass plate is laid on this machined surface, and the assembly is heated in a furnace above the softening point of the glass. The glass forms a bond with the metal surface, the temperature being held so that the resultant glass is concave, forming a uniform-thickness layer over the whole surface. Cooling is done in as many hours as months required in the all-glass mirror. The surface is then ground to the proper shape. Advantages of the glass-metal combination are easy machineability, good conductivity, excellent surface, and the advantage of coating glass by aluminum. H.K.R.

Tensile tests of glasses. W. L. SCHWALBE, A. E. BADGER, AND W. B. SILVERMAN. *Jour. Amer. Ceram. Soc.*, **21** [10] 333–38 (1938).

Theory of scattering of light. HANS MUELLER. *Proc. Roy. Soc.* [London], **A166**, 425–49 (1938).—A new theory of the scattering of light in glasses is based on the assumption that glasses contain a random distribution of "frozen in" strains. Slightly below the solidification temperature these strains are normal, but at lower temperatures shearing strains are created due to temperature contraction. These strains do not originate by chance, but they are an intrinsic property of every glass and can not be removed by any process of annealing. A.P.

Ultra-violet light transmission of sheet glass. V. ČTYROKÝ AND M. FANDERLIK. *Sklářské Rozhledy*, **15**, 51–58 (1938); *Glashütte*, **68** [27] 455–59 (1938).—The ultra-violet light transmission of ten sheet glasses 5 to 7 mm. thick was determined using a Hilger medium quartz spectrograph and Spekker photometer. Results are given in tabular form and as spectral transmission curves. All the glasses are of drawn sheet glass and the results refute the statement of O. Knapp (see "Sheet—," this issue) that such glasses had only poor ultra-violet transmission. Five of the glasses examined transmitted much ultra-violet,

and the biological efficiency (percentage of efficiency of direct sunlight) was 10 to 15% for glasses 3 mm. thick and 20 to 30% for glasses 1.8 mm. thick. E.P. + M.V.C.

PATENTS

Apparatus for:

Decorating bottles, etc. OWENS-ILLINOIS GLASS CO. Brit. 489,804, Aug. 17, 1938 (June 18, 1936).

Distributing molten glass. SOC. FRANÇAISE DES VERRERIES MÉCANIQUES CHAMPENOISES. Fr. 823,694, Jan. 25, 1938; *Chem. Abs.*, **32,** 6019 (1938).

Drawing sheets of glass. GLASS IMPROVEMENTS, LTD. Fr. 823,709, Jan. 25, 1938; *Chem. Abs.*, **32,** 6020 (1938).

Fusing glass. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 825,529, March 4, 1938; *Chem. Abs.*, **32,** 6418 (1938).—An electric current is passed through the mass of glass.

Making glass fibers by extrusion through fine orifices. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 822,336, Dec. 28, 1937; *Chem. Abs.*, **32,** 4297 (1938).

Making glass filaments. SOCIETÀ ANON. VETRERIA ITALIANA BALZARETTI MODIGLIANI. Fr. 824,093, Feb. 1, 1938; *Chem. Abs.*, **32,** 4297 (1938).

Molten glass. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 823,605, Jan. 24, 1938; *Chem. Abs.*, **32,** 6019 (1938).—Apparatus of refractory clay is covered with Pt which has a backing of Rh or a Rh-Pt alloy. If the molten glass comes in contact with the apparatus intermittently, the Pt may be protected both back and front by Rh or Rh-Pt.

Apparatus for and method of feeding molten glass. W. T. HONISS (Hartford-Empire Co.). U. S. 2,128,249, Aug. 30, 1938 (Dec. 30, 1935).

Bifocal lens. DAVID SLOTSKY. U. S. 2,129,243, Sept. 6, 1938 (June 9, 1936).

Bond for mineral or rock wool. A. H. FESSLER (General Motors Corp.). U. S. 2,128,290, Aug. 30, 1938 (Nov. 8, 1935).

Cellular glass. VLASTIMIL STRAKA. Fr. 826,054, March 22, 1938; *Chem. Abs.*, **32,** 6417 (1938).—Powdered glass is fused in a sealed mold with a substance which liberates a gas in an amount which increases as the temperature rises. $CaCO_3$ is a suitable substance. Inert fillers, *e.g.*, sand or clay, may be included in the mixture. Examples are given.

Compound glass. I. G. FARBENIND. A.-G. Ger. 660,904, May 12, 1938 (April 28, 1930); 39*b*. 27. Compound glass is made by joining the glass layers with a layer produced from polyvinyl alcohol or its derivatives. D.A.B.

Cooling glass articles, especially glass plates, by means of air, etc. CURT RICHTER. Ger. 660,539, May 5, 1938 (Sept. 29, 1936); VI/32*a*. 30. Air from special tubes is blown against the glass articles, and the heated air is withdrawn in a corresponding amount by other tubes. The inlet and outlet tubes for the cooling agent are provided with numerous openings, extend lengthwise over the entire glass object, and, in the space along the sides, are fastened by a fixed revolving axle which lies parallel to the glass article so that a centrifugal action is exerted on the withdrawn cooling agent. D.A.B.

Drawing sheet glass. DEUTSCHE TAFELGLAS, A.-G. (DETAG). Ger. 652,153, May 5, 1938 (June 1, 1934); VI/32*a*. 23.03. Sheet glass is drawn in a plant operating without heating the base of the drawing hearth. The temperature of the glass bath in the hearth is regulated by a divided heating space (each being regulated in itself), which is parallel to the longitudinal direction of the nozzle slot, in the glass bath for maintaining and reproducing uniform glass at the drawing place. D.A.B.

Glass etching. G. R. MCKAY (McKay Co.). U. S. 2,127,781, Aug. 23, 1938 (March 12, 1936). A process of etching glass includes the steps of coating that portion of a pervious screen surrounding the design to be etched with a suitable acid resist, positioning the coated side of the screen against the glass, and applying to the uncoated side of the screen an etching compound of such consistency that the interstices of the screen will not become clogged and a maximum concentration of etching agent is deposited on the glass.

Glass-grinding apparatus. PILKINGTON BROS., LTD., AND F. B. WALDRON. Brit. 489,661, Aug. 17, 1938 (Feb. 1, 1937).

Glassware-forming apparatus. E. G. BRIDGES (Lynch Corp.). U. S. 2,129,614, Sept. 6, 1938 (Feb. 13, 1930).

Glazing glass. FREDERICK GELSTHARP (Pittsburgh Plate Glass Co.). U. S. 2,128,702, Aug. 30, 1938 (June 16, 1936). A lime soda, high silica, substantially colorless and nonblooming sheet of glass comprises approximately 70 silicon dioxide, 7.5 potassium oxide, 15 calcium oxide, 1.1 antimony oxide, and 0.1% of aluminum and iron oxides, with a sodium oxide content of not more than 6.5% by weight of the weight of the glass.

Leer construction. J. F. GREENE (Kimble Glass Co.). U. S. 2,129,057, Sept. 6, 1938 (Oct. 31, 1935).

Manufacture of a clear transparent safety glass. RÖHM & HAAS, A.-G. Ger. 660,634, May 5, 1938 (March 14, 1928); IV*c*/39*b*. 27. Safety glass is made from glass panes and a shatterless binding agent derived from resins. The layer rendering the glass shatterproof and binding the glass panes consists of flexible, elastic films of polymerized products of ethyl or methyl esters of acrylic acid or a mixture of both without the use of cellulose esters. D.A.B.

Manufacture of patterned hollow glass articles from opal or colored crystal flash glass. SÄCHS. GLASFABRIK AUGUST WALTHER & SÖHNE, A.-G., AND BARUTHER GLASHÜTTENWERKE ALFRED KAISER. Ger. 655,760, Jan. 6, 1938 (Sept. 18, 1935); VI/32*b*. 7. Addition to Ger. 567,-911. A method is described in which the hollow glassware is made with internal designs. The designs are produced on the inner surfaces of the glassware by sandblasting. D.A.B.

Manufacturing glassware. C. W. JOHNSON. U. S. 2,125,789, Aug. 2, 1938 (Nov. 12, 1934).

Method and apparatus for making glass tubes and rods. KIMBLE GLASS CO. Ger. 661,570, May 28, 1938 (Jan. 23, 1936); VI/32*a*. 27. U. S. 2,059,474 (*Ceram. Abs.*, **16** [1] 18 (1937)). D.A.B.

Mirror-plating apparatus. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 2,128,713, Aug. 30, 1938 (Aug. 13, 1937).

Ophthalmic mounting. J. W. ASPENLEITER (Bausch & Lomb Optical Co.). U. S. 2,129,520, Sept. 6, 1938 (Dec. 16, 1935).

Production of foam glass. J. KLOUBEK AND B. WEINER. Brit. 490,168, Aug. 24, 1938 (Aug. 31, 1936).

Rock wool blow chamber. A. F. MILLER (Marquette Cement Mfg. Co.). U. S. 2,129,434, Sept. 6, 1938 (Jan. 25, 1937).

Tempering glass. W. SIGMONT. Australian 102,920, Jan. 20, 1938; *Chem. Abs.*, **32,** 4297 (1938).—In an apparatus for tempering, the glass is supported horizontally during both the heating and the chilling steps, and the supports are in motion relative to the glass during the chilling.

Vehicle lamp glasses. R. BOSCH GES. Brit. 490,190, Aug. 24, 1938 (Dec. 22, 1936); addition to 399,455.

Structural Clay Products

Automatic sanding machines. W. ENGELS. *Tonind.-Ztg.*, **62** [6] 67 (1938).—Apparatus for sanding the clay column as it is extruded from the machine on the bottom and on the sides is described. Illustrated. W.K.

Porous brick. W. RUF. *Tonind.-Ztg.*, **62** [11] 122 (1938).—The amount of fine coal added to the clay to produce porosity should not be more than 50%. Good mixing and drying is essential. The firing should be done

carefully to avoid local overfiring. The strength should be 130 to 180 kg./cm.². In the manufacture of ordinary brick, an addition of coal dust is often beneficial because it helps the drying and cuts the weight of the finished product. W.K.

Prevention of efflorescence in the manufacture of brick. WALTER MARSCHNER. *Schweiz. Tonwaren-Ind.*, **39** [5] 6–7; [6] 4–5 (1936); *Chem. Abs.*, **32**, 6414 (1938).—The source and cause of efflorescence and its prevention by the addition of $BaCO_3$ in the preparation of the clay are discussed.

Properties of brick and their most effective utilization. H. HECHT. *Tonind.-Ztg.*, **62** [19] 207–12 (1938).—H. discusses in detail the properties of brick, such as strength, permeability to air and water, water absorption, and thermal and acoustical insulation, the standardization of these properties, and methods of testing. W.K.

Setting of vitrified brick. ANON. *Tonind.-Ztg.*, **62** [10] 106–107 (1938).—The weight of a column of brick set in a kiln depends solely upon the height, which should not be more than 2.50 m. The stability varies with the manner of setting, owing to the variation of the effect of the fire. The best way to avoid excessive warpage and losses is to set the brick flat. W.K.

PATENTS

Brick for surfacing roads, etc. G. V. PARKER. Brit. 490,142, Aug. 24, 1938 (Feb. 9, 1937).

Building wall construction. JOSEPH ROSE. U. S. 2,128,886, Aug. 30, 1938 (Feb. 23, 1938).

Combined preparation and press equipment for occasional production of sand-lime brick. WILHELM REINEN. Ger. 655,830, Jan. 6, 1938 (Feb. 7, 1936); VI/80a. 1.05. The equipment consists of two preparation plants, independent of each other, for the raw materials which are in conjunction with a common press plant. D.A.B.

Composition. N. J. DUNBECK (Eastern Clay Products, Inc.). U. S. 2,128,404, Aug. 30, 1938 (Nov. 1, 1937). In a composition of matter, a mold composition comprises, in combination, sand and a nonswelling clay of which montmorillonite is a large constituent.

Composition building block. C. A. HADLAND. U. S. 2,127,914, Aug. 23, 1938 (Dec. 24, 1936).

Forming porous bodies. A. M. HARVEY. U. S. 2,127,867, Aug. 23, 1938 (March 26, 1936). A method of making porous bodies includes mixing 15 to 20% by volume of clay and 80 to 85% of combustible granules, adding water to the mixture to form a plastic mass, forming the mass into bodies of the shape desired, placing one face of each body upon a heat-insulating support, and applying heat at gradually increasing temperatures to the opposite face of each body to form in the body a series of pores connected to the opposite face thereof by passages formed by gas pressure resulting from the combustion of the granules.

Manufacture of brick. L. CZAJKO. Swiss 196,915, June 18, 1936; *Chem.-Ztg.*, **62** [58] 529 (1938). D.A.B.

Refractories

Acceptance tests on refractories. R. RASCH. *Chem.-Ztg.*, **62** [22] 193–96 (1938).—A number of tests are recommended for fire brick. Although these tests are mainly physical, the chemical tests are not to be excluded. Externally, the fire brick is to be checked for cracks, ridges, cavities, uniformity of shape of brick, wave formations, filling up of cracks by smearing with water glass, aluminum, and sodium phosphate (readily rendered visible by the use of phenolphthalein), and other errors due to fabrication. Internally, the brick is checked for air holes, cavities, cracks, texture, foreign bodies, porosity, etc. The atmosphere in which the brick is to be used, stability of brick to heating and cooling, constant volume, pressure due to heating, chemical composition of brick, and purity and quality of ingredients are other factors to be checked before purchasing fire brick. Six illustrations. See *Ceram. Abs.*, **17** [5] 185 (1938). D.A.B.

Better metal from blast furnaces and open hearths. I. A. OEHLER. *Metal Progress*, **33** [6] 579–83 (1938).—Thermal insulation of open-hearth furnaces has brought fuel economies, but in some cases these have been offset by decreases in roof life; in other cases improved roof life was reported. F.P.P.

Ceramics and refractories. E. F. ARMSTRONG. *Jour. Roy. Soc. Arts*, No. 4472, pp. 949–50 (Aug. 5, 1938).—A. pays tribute to J. W. Mellor ("Passing—," *Ceram. Abs.*, **17** [10] 344 (1938)). Ceramic research can be expected to lead to ever-increasing use of fired products made from the earth's common minerals, and every advance made in the quality of refractory products is attended by an improvement in all manufacturing processes dependent on furnace operations. In the factory there has always been the desire to push the temperature up a little higher to gain better results. Thus, in the gas industry a start was made by carbonizing in cast-iron retorts at 750° to 900°, with a consequent low yield of gas. By 1850 fireclay retorts were in successful commercial use; by 1885 the yield of gas had risen from 6000 to 10,000 cu. ft. per ton of coal. This, however, did not satisfy the gas engineer. By using silica retorts, nearly twice this yield is obtained. The development of ceramic art is traced from simple beginnings through mazes of complication; maturity now indicates a return to simplicity. Glassblowers' batch books in 1850 were a mixture of superstition and experimental-technical knowledge, with a gold-piece sacrificed to every batch. Manufacturers of clay products, following alchemists' technique and working with a multitude of clays, mixed and blended, modifying white-firing, buff-firing, and red-firing clays, plastics and nonplastics, fireclays, and sands. Today texture plays an important part in the effective life of a refractory material; it is influenced by grinding, screening, and mixing of the raw material, pressing and molding, and drying and firing. The most important factors seem to be (1) grain size of the clay, (2) nature, amount, and grade of grog added, and (3) the firing operation. Grog is prefired clay, varying quantities of which are worked up with the clay until a homogeneous mixture is obtained. The purpose of this addition is to reduce shrinkage in the clay body during drying and firing, thus insuring accuracy in size and shape. Shapes are dried and fired according to plan to produce a finished brick having strength, shape, and the particular properties necessary for its purpose. During the firing treatment (over 900°) partial fusion of the various mineral constituents takes place. A fireclay brick is essentially a vitrified product containing three crystalline substances in varying quantities. The modern trend in refractories is toward a product of high bulk density, with improved properties of great industrial significance. High proportions of nonplastic material are used; much depends on the mixing operation, whose function causes the grog particles to be thoroughly coated with minimal amounts of plastic clay. High pressures are required for molding; air, as far as possible, should be eliminated from the mixture. The function of the firing operation is to mature the bond, rather than to vitrify the mixture, avoiding strain; greater durability results. Progress requires the study of factors influencing durability, thus altering the principle of manufacture. Experiments are being made in America with unfired refractories, *i.e.*, those which receive their first firing in use. Special refractory materials are being made in the electric furnace. A good brick must show neither after-expansion nor contraction; retorts must not fail under load; the refractory must be stable to temporary fluctuation in temperature and resist attack by slags. Experiments of the past decade have had immediate results in practice; the gas industry gets better results from coal; "using" industries store

their refractory and silica brick when they are not in use. These industries realize their dependence on effective use of the furnace. K.R.

Choosing refractories for the superstructure and regenerators of modern glass tanks: I, Refractories and insulating materials. W. F. ROCHOW AND J. SPOTTS MCDOWELL. *Amer. Glass Rev.*, **57** [38] 9–12 (1938). **II, Refractories in the glasshouse.** *Ibid.*, [39] 9–12; [40] 9–12.—A review of the types and properties of refractories available for glassmelting furnaces is presented. A.P.

Considerations in the production of fused mullite for refractories. HOBART M. KRANER. *Jour. Amer. Ceram. Soc.*, **21** [10] 360–66 (1938).

Expansion characteristics of kyanite and kyanite-clay mixtures when heated. GORDON R. POLE AND D. G. MOORE. *Bull. Amer. Ceram. Soc.*, **17** [9] 355–67 (1938).

Failure of coke-oven walls by reaction with coal ash. W. C. RUECKEL. *Jour. Amer. Ceram. Soc.*, **21** [10] 354–60 (1938).

High-grog refractories with a mullite bond. V. A. RYBNIKOV AND P. P. ALIMOVA. *Keram. & Steklo*, **14** [4] 12–14 (1938).—By firing grog brick with a mullite bond to 1650°, high-grade refractories were produced which have a very low apparent porosity (0.26 to 0.37%), high mechanical resistance (3137 to 3465 kg./sq. cm.), incipient softening under load at 1600°, and a high chemical resistance to soda (94.6 to 96.4%). Their disadvantages are high water content of the mix, high shrinkage (7.2 to 7.5%), and a low thermal resistance. M.V.C.

High-temperature refractories. HENRI GEORGE. *Jour. Four Élec.*, **47**, 127–28 (1938); *Chem. Abs.*, **32**, 6416 (1938).—G. briefly describes the principal high-temperature refractories. Pure Al_2O_3 is expensive; the natural form, corundum, 94 to 97% pure, is satisfactory commercially. Zircon, $ZrO_2 \cdot SiO_2$, may be decomposed by heating, and the mixed oxides used as such, or the SiO_2 may be leached out by caustic. ZrO_2 is inert to metals and withstands high mechanical loads and temperature variations; C affects it above 1500°. MgO, when melted at 3000°, distils off most of its impurities and yields a more inert but expensive product than calcined MgO. When mixed with chromite to make brick good to 2000°, the proper screen sizes of fused MgO produce optimum thermal or mechanical properties. Thoria must be calcined or melted in an oxidizing atmosphere; it stands high temperatures and is easily formed into crucibles and other shapes but is attacked by C and SiO_2 and has a high coefficient of thermal expansion. A good chromite has an Fe:Cr ratio less than 1:3 and is inert to metals, fluxes, and SiO_2.

Impact bending strength of ceramic bodies and glasses and its relationship to the resistance to thermal shock of fireclay bodies. OTTO BARTSCH. *Ber. Deut. Keram. Ges.*, **18** [11] 465–89 (1937).—The difference between the true and the apparent impact strengths is pointed out. The apparent impact strengths of a number of fireclay bodies and of glasses in annealed and unannealed condition were determined. Comparison with other ceramic bodies showed that glasses had the highest values and earthenware and fireclay bodies the lowest, while vitrified bodies such as stoneware and porcelain occupied an intermediate position. The impact strength of fireclay bodies of extremely fine grain increased with rising firing temperatures, but for bodies made with normal grog a maximum strength was observed at about 1000°. The influence of the number of quenchings in the spalling test on the impact strength of fourteen fireclay bodies was also studied. Great differences were observed in expansion behavior, density, grain-size distribution, and firing temperature. Bodies fired above 1200° showed increasing reduction in impact strengths with rising firing temperature; below 1200° the relationship is more complicated. A particularly high spalling resistance was found in two fireclay bodies fired at 1000°. E.J.V.

Improvements in crucible melting furnaces. R. D. HAWKINS AND O. D. PRITCHARD. *Ind. Heating*, **5** [8] 704–708 (1938).—Practical operating data on controlled melting and control of furnace atmosphere are given which reduce the volume of the flue gases and improve the temperature distribution in the furnace as compared with that in older furnaces. Mullite and sillimanite are used extensively for the inner rammed lining. M.H.

Insulating fire brick as a furnace lining. R. S. BRADLEY. *Mining & Met.*, **18** [367] 331–34 (1937).—B. gives a general account of the development of insulating fire brick, their properties, and their advantages and limitations in use. Heat balances on two furnaces, identical except for the type of linings, are discussed, and the advisability of using a lightweight fire brick for lining intermittent furnaces whenever practicable is shown. E.J.V.

Linear thermal expansion of "beta-alumina." J. B. AUSTIN. *Jour. Amer. Ceram. Soc.*, **21** [10] 351–53 (1938).

Linings in low-frequency induction furnaces. ALEX. SEVASTOPOULO. *Jour. Four Élec.*, **47**, 165–67 (1938); *Chem. Abs.*, **32**, 5705 (1938).—These linings have been improved so that 3000 pourings of a brass of 28% or more Zn or 800 pourings of Cu are possible. Hearth and walls may be of preshaped brick or tamped and fired in place. Present compositions run from 55 to 90% SiO_2, the remainder being mainly Al_2O_3.

Manufacture of silica brick by the Dominion Steel and Coal Corp., Ltd., Sydney, N. S. H. B. GILLIS AND F. C. MORRISON. *Trans. Can. Inst. Mining & Met.*, **41** (in *Can. Mining & Met. Bull.*, No. 312), 159–66 (1938). A.H.E.

Methods for producing refractory zirconium oxide ware. VLADIMIR ŠKOLA. *Zprávy Československ. Keram. Společnosti*, **12**, 53–55 (1935); *Chem. Abs.*, **32**, 4295 (1938).—Baddeleyite is produced either by (1) fusing in an electric furnace with a high-quality clayey raw material (such as natural emery) and pouring the melt into forms (commercial product "Jargal") or (2) grinding the ore fine, leaching with H_2SO_4, heating the sulfate at a high temperature, and obtaining ZrO_2. Hot ZrC can be treated with Cl, and the resulting $ZrCl_4$ can be converted into the oxide by heating at a high temperature.

Recovery of alumina and fertilizers from Chinese alunite: III-e, Extractability of natural alunite with potassium hydroxide. G. HOHORST AND HSIANG-LIN HOW. *Jour. Chem. Eng. China*, **4**, 227–33 (1937).—Best extraction of unignited alunite requires not less than 12 *N* KOH in 13% excess. By treatment for $^1/_2$ hr. at 80°, yields of more than 96% of Al_2O_3, SO_3, and K_2O are obtained. The SiO_2 content in dissolved Al_2O_3 is 0.32%; the Fe_2O_3 content of the solution is less than 0.01%. **III-f, Extraction of alumina with sodium hydroxide after recovery of potash and sulfur trioxide with ammonia.** G. HOHORST AND HSIAO-HAI WANG. *Ibid.*, pp. 234–47; *Chem. Abs.*, **32**, 6012 (1938).—In extraction of ignited alunite with 12.5% aqueous NH_3, the heat of reaction may be usefully employed, the temperature rising to 70°, with more than 94% extraction of SO_3. Treatment of the residue with NaOH at 80°/1 atmosphere, the $Na_2O:Al_2O_3$ ratio being 1.7 to 1.8:1 mol., dissolves more than 93% of the Al_2O_3. The solution is suitable for Al_2O_3 recovery by stirring after seeding (Bayer process) (70 to 77% yield). The average SiO_2 content of the solution is 0.55 g./liter. Extraction under pressure increases the formation of insoluble Na Al silicate. The NaOH concentration is not critical; solid may be added to the residue or used solutions employed for extraction purposes. Ni apparatus is suitable. The product is practically free from Fe, and the SiO_2 content is sufficiently low for metallurgical purposes. For Part III see *Ceram. Abs.*, **16** [7] 208 (1937).

Refractories. GENERAL REFRACTORIES, LTD. *Foundry Trade Jour.*, **57**, 214 (1937).—In the Foundry Trades' Exhibition at Olympia the importance of refractory materials is stressed. There has been a tendency to use more synthetic molding sands to insure better standardization. Basic and neutral refractories are included in Supermag and Diazite. Saxpyre brick are being used from the bottom of the hearth to the slag line. Spinella brick are designed for the upper structures which are sub-

jected to conditions of greater temperature fluctuations in open-hearth and electric furnaces. These brick are of a chrome-spinel type. High-temperature cements and heat-insulating materials are also shown. H.E.S.

Refractories in steel manufacture. ANON. *Iron & Steel Ind.*, **11** [9] 351–454 (1938).—In an open-hearth symposium the writers contributed the following statements on refractory materials:

Cost: The refractories used in steel production cost about five shillings ($1.00) per ton of steel produced in the form of rolled or forged metal. About one half of this is required for open-hearth furnaces, particularly in the roof, ramps, checkers, and blocks.

Acid open-hearth furnaces: The best silica brick and fireclay brick are generally used. The general trend is to provide a robust reinforcement because silica brick have a high expansion and, on repeated rebuilding, form a structure which is not mechanically strong and can be seriously distorted. The average weight of silica brick used in the furnace (including renewals) is 45 lb. per ton of steel; half of this is required for the make-up of the hearth.

For maintaining the hearth the metal pockets are rabbled out and, in the "dry-off" method, are dried with unfired silver sand; the gas is shut off and the metal-sand debris removed; after heating, new fettlings are fired on. In an alternative method the gas is kept on all the time, the pockets are fettled after each heat, and the debris is left at the bottom. The second method saves time and is quite satisfactory if an adequate slope to the tap-hole is maintained.

Basic open-hearth furnaces: These furnaces have increased 132% in nine years, but very little alteration has been made in furnace design. To increase the output, new basic refractories, both in the upper structure and in the checkers, are desired. Basic open-hearth furnaces in the future will be built of special basic brick for roofs and ports, with a cheaper basic brick of lower refractoriness under load for the back and front linings. For the hearths, adequate thickness and good quality of refractory are essential, particularly near a tap hole; insulation is desirable. The bottoms should have a 12-in. lining of magnesite on which tar and burned dolomite are pneumatically rammed. Magnesite brick should extend all around to 12 in. above the fore plate level. In one works the bottoms are 24 in. thick at the foreplate level and set back gradually to a thickness of 18 in. at the skewback. For the sides and roof, first-class silica brick are preferred. The roofs are 9 in. or 12 in. and the ramps are 9 in. thick. In some furnaces, the silica tapers to 18 in. at the skewback. The trend is toward basic brick walls and jambs, protected adequately by insulation. Excessive spalling is often traceable to lack of sufficient compression in the roof. For ports and blocks, the use of chrome-magnesia refractories has given most encouraging results and increased durability, but in most basic furnaces the port blocks are of silica. When open-hearth furnaces are working at full capacity, the refractory consumption increases in proportion to the output. If T = total therms per ton and O = output in tons per hour per 100 tons capacity, then $T = 45 - 50 + 5.3\ O$. For reducing this, the greatest hope lies in newer and better basic refractories, but every attempt to build a furnace (particularly the roof) of magnesite brick has resulted in failure.

Regenerators: In acid furnaces, the uptake and topmost checkerwork become choked much more quickly than in basic furnaces, and the more frequent cooling reduces the effective life of the brickwork. The choking is due to almost pure ferric oxide, much of which adheres tenaciously to the brickwork. The use of basic checkers has been suggested.

Runner brick: These brick are used only once, so durability need not be considered; price is a factor, but the most important consideration is the influence on the cleanness of the steel. A thorough investigation of the relation between the physical and chemical properties of runner brick and the nonmetallic inclusions in steel is badly needed.

Stopper sleeves and nozzles, guide tubes, and runner brick: Materials less sensitive to slags are now used; these have improved the quality of the metal. In a works near Sheffield wet jointing was abandoned, and dry setting for stoppers, trumpets, and runners was used. Pitside accessories of the rib-and-groove type are better than those of the stepped-end type, and break-outs through the runners in uphill casting are now rare. In basic furnaces, nozzles made of fire brick are preferred, but the use of composite magnesite nozzles is increasing.

Ladles: These vary greatly in capacity; those used at Cardiff hold 90 tons of steel, but the usual pour is 85 tons. The lives of such ladles are 25 to 26 casts per lining (calculated from actual consumption in pounds of brick per ton of steel over six-month periods), sufficient justification for the purchase of good-quality brick which erode at only half the rate of common brick and discharge into a ladle of steel only half the siliceous matter which goes to swell the inclusions. The quicker the ladle is emptied, the longer is the life. The hotter the brick, the more are they eroded; hence, in bottom-poured steel there is much less erosion. The amount of wear on a ladle lining depends largely on the depth of slag present. There is much difference of opinion about ladle brick. Some users find that fireclay brick are no better than silica brick; others prefer fireclay brick. Two types of fireclay brick have given good service, *viz.*, medium alumina (35 to 40%) and low alumina (25 to 30%). Low-alumina brick expand considerably on heating, producing tight joints, while their low melting point leads to reduction in penetration. Clay-graphite brick possess great slag resistance. If the difficulties with jointing material and skull formation can be overcome, such brick might prove economical in spite of their high initial cost. In one works near Sheffield, the "parging" of shoots and ladles has been stopped, and the increased cost in refractories has been balanced by using better linings which, being more durable, cost no more per ton of steel produced and give a cleaner steel.

Silica brick: If well fired and of high quality, silica brick can carry heavy loads to within a few degrees of their melting point, the safety limit being about 1650°C. They spall badly at low temperatures and have only a small safety range in regard to melting, but their volume stability and high refractoriness under load go a long way toward compensating for these limitations. They are still used in the roofs of open-hearth furnaces and will continue to be until chrome-magnesite brick of much lower bursting tendency are available. There is still much difference of opinion as to whether soft or hard-fired brick are better. The former possess greater initial thermal shock resistance, but they can not be produced with the control used with harder-fired materials; thus, it is quite possible to fire a beehive kiln until the whole of its contents has a specific gravity between about 2.32 and 2.35, but practically impossible to fire it so that all its contents have specific gravities between about 2.40 and 2.43. Experiments with basic brick as a substitute for silica brick in linings exposed to the furnace atmosphere have failed. Silica brick, in use for some time, are no longer pure silica but silica impregnated with various metallic oxides and have a much-reduced melting point. This fact is often overlooked when considering the durability of silica brick. Spalling of silica brick used for hot patching can be reduced by boiling them in tar or immersing them in creosote.

Magnesite brick: Great improvement has been made chiefly by (1) using a mixture of magnesia and chromite, (2) better control of the grading, and (3) forming a forsterite bond in a chrome-magnesite brick. In such brick, spalling appears to be due not to thermal shock but to a solid solution of iron oxide in chromite being formed and to the great expansion and stress resulting therefrom. The refractoriness under load is usually 1500° to 1700°C, but subsidence commences at least 200°C below the point of rapid collapse.

Nonspalling magnesite brick suffer from "structural spalling." X-ray examination before and after use shows that the crystals have increased in volume about one thousand times. Magnesite brick, although much im-

proved in their properties, are tending to be displaced by chrome-magnesite and dolomite brick.

Dolomite brick: Until recently, dolomite brick were inferior to magnesite brick. Some hydrated even before installation, while others dusted on cooling, on account of the large expansion accompanying the inversion of β- to γ-dicalcium silicate. Dolomite brick free from these limitations are now produced. They can be boiled in water for a week without falling and show no signs of dusting when used under the hearths or in the door jambs of open-hearth furnaces. Their use under the hearth and in tap-hole linings, etc., has resulted in considerable savings in steelworks, as their cost is less than two-thirds that of magnesite brick. The experience at a new plant at Hartlepool for the extraction of magnesia from dolomite suggests that magnesia from this source is particularly suitable for the manufacture of refractories. Brick made from the first batch of material possessed an abnormally high degree of thermal shock resistance and a high refractoriness under load.

Chrome-magnesite brick: Brick with a high resistance to thermal shock are available, but they tend to swell and burst on absorbing iron oxide. Certain chrome-magnesite brick undergo a much smaller expansion (about 17%), while laboratory test pieces, in which the expansion was reduced to 7%, suggest that such brick have great potentialities provided the bursting tendency can be overcome. Chrome-magnesite brick used on the end-stoppers of gas and air ports of open-hearth steel furnaces last six times as long as silica brick. Waste chrome-magnesite brick make an excellent cement, but there is no demand for such large quantities of basic cement. At a steelworks near Sheffield they are used for constructing a backwall of metal-case magnesite tubes embedded in the ground waste brick. Although the space left between the tubes was considerably greater than usual, the backwall proved quite durable.

Insulation: The insulation of slag pocket walls and regenerators can be justified on the grounds of both economy and convenience. The progress in roof insulation in America has been associated with a particularly suitable insulating material, and another contributory factor toward this development has been the use of a thicker roof than that used either on the Continent or in Great Britain. The result is a longer life of the refractories (from 300 to 500 heats), provided that temperature control is adequate. This is ascribed to the greater depth of penetration of tridymite conversion.

Economies of fuel practicable with a new furnace are estimated as follows:

	Saving of heat supplied to the furnace (%)
Working chamber: roof	3.6
Walls and jambs	1.5
Downtakes and port ends	5.7
Slag pockets and regenerators	3.5
	14.3

The insulation of reheating furnaces is now taken for granted. For continuous reheating furnaces, insulation of the diatomite type (thermal conductivity 1.0 B.t.u. at 500°C mean temperature) is generally used behind a fireclay-brick lining. For periodic furnaces, where a great deal of the heat from the fuel is lost during the shutdown period, the possibility of hot-face insulation should be considered. Furnaces in which clean gas is used and in which there is no heavy abrasion or vibration can be built entirely with high-temperature insulating brick and operated quite successfully and economically to temperatures of at least 1300°C. The life of hot-face insulation can be considerably increased by accurate shaping and by coating the brick with suitable cement. The lining of a recuperator constructed in this way has been in use for about a year without repair.

Reheating furnaces: Brick should be selected according to the conditions involved; thus, with heat-treatment furnaces operating at about 900°C, a highly refractory brick is not required, but abrasion resistance and price are important. In hearths for mill and forge furnaces, the semimolten scale must usually be removed (together with a good deal of brick) by chipping; only rarely can the scale be liquefied and run off. Fireclay brick, particularly the low-alumina type, rapidly flux away; chrome-magnesite brick resist slag attack but tend to burst owing to iron oxide absorption. The life of the brick is short because they are torn away with the slag at the cleanout. Forsterite and dolomite brick have given fair service, and monolithic hearths made from chrome-magnesite mixtures, using aluminous cement and other bonds, have also proved useful. They should form a thin but strong layer on top of brickwork so that they can be removed with the scale without damage to the foundation.

Soaking furnaces: These furnaces, in which the scale is liquefied by adding crushed semisilica brick containing 8% of alumina, are usually lined with either chrome or magnesite brick or, recently, with chrome-silica brick, which give equal service and are much cheaper.

Specifications: It is difficult and often dangerous to specify the type of refractory required for each purpose, but tentative specifications, *e.g.*, for silica brick, are already in use, and the quality of materials is constantly being compared with the values suggested. Great variation in results occurs when different test procedures are employed, but sufficient experience has been obtained to show that where similar methods of testing are employed similar results are obtained. A.B.S.

Refractory problems in the iron and steel industry. FELIX SINGER. *Iron & Steel Ind.*, **11** [8] 316–20; [10] 479–82; [12] 575–80 (1938).—S. reviews the entire field of the application of refractories in ferrous metallurgy and the characteristics of various types of refractories. In no other field is the application of science more desirable, and nowhere else is purely scientific research opposed by so many difficulties. Technical standardization is highly desirable but the norms of durability and economy can not be standardized. There is, therefore, much in favor of practical work and empirical information. 76 references. E.H.McC.

Relationship between structure and life of silica brick in the roof of an open-hearth steel furnace. Author's reply to discussion. V. L. BOSAZZA. *Jour. Chem. Met. Mining Soc. S. Africa*, **38** [9] 398–405 (1938).—B. replies to discussions of two papers (*Ceram. Abs.*, **17** [5] 187, 188 (1938)) and includes some information obtained since their publication. E.H.McC.

Separation of lime and magnesia in dolomite. J. J. FRANKEL. *Jour. Chem. Met. Mining Soc. S. Africa*, **38** [6] 237–55 (1937); **38** [9] 387–90 (1938).—In South Africa, magnesite is rare, and calcitic limestone is much less common than dolomite which yields "blue lime." There is a demand for a cheap process for treating dolomite to produce (1) a magnesia-free lime for cement making and (2) magnesia for brick, flooring materials, etc. F. discusses (*a*) chemical methods, usually employing "external" reagents, and (*b*) solution methods, in which the only reagents are water and waste gases. Economy seems to favor solution methods, notably the Pattinson process (a basic magnesium carbonate method). E.H.McC.

Sintered magnesite: III, Sintering process in magnesite containing unevenly distributed constituents. K. KONOPICKY. *Ber. Deut. Keram. Ges.*, **18** [9] 419–27 (1937).—K. studied the effect of unevenly distributed impurities on the sintering process of raw magnesite. Quartz, magnesium silicates, dolomite, and dolomitic magnesites, in the form of nests or bands, react only slightly with the ground mass during sintering. The sintering process is therefore practically determined by the composition of the ground mass (the "pure" raw magnesite). The known sinterable raw magnesites have, as ground mass, mostly an isomorphous mixture of Mg-Fe-Ca-carbonate, the composition of which is often completely obscured by the unevenly distributed impurities. Nonsinterable raw magnesite can be sintered in lump

form by the addition of fluxes if the additions contain appreciable amounts of dicalcium ferrite and are poor in silica. Most of the impurities, particularly those of a silicate nature, can be removed by subsequent physical treatment. For Part II see *Ceram. Abs.*, **17** [2] 74 (1938). E.J.V.

Soviet mullite. A. A. LITAVAKOVSKIĬ AND M. V. OSIPOV. *Keram. & Steklo*, **14** [4] 4–10 (1938).—The characteristics of mullite refractories, raw materials used, and properties of Russian mullite brick are discussed. M.V.C.

Use of hydraulic cements in refractory concrete masonry: I. M. LÉPINGLE. *Chaleur & Ind.*, No. 216, pp. 271–81 (1938).—L. mentions the influence of the compositions of grog and bond on the resistance of a refractory to failure under load and gives the compositions of four classes of hydraulic cements (Portland, tricalcium silicate, alumina, and slag cements) with their setting properties and cold strengths. Prolonged desiccation at 200°C. and firing at 1080°C caused complete disintegration of the Portland cements and the tricalcium silicate cement, although both resisted failure under load up to 1300° when heated above 500° at the rate of 5°/min., owing to a sintering action before all the water of hydration had passed off. In alumina cements, the water appears to be held in a zeolitic condition and passes off without disrupting the crystalline structure. The chemical composition of the alumina cement also plays a part in its excellent resistance to failure under load at high temperatures. The higher the ratio of cement to aggregate, the greater is the shrinkage on cooling and the lower is the P.C.E. value. L. discusses in detail the compounds and eutectic mixtures present in a number of concretes, using the SiO_2–CaO–Al_2O_3 phase-equilibrium diagram of Rankin. **II.** *Ibid.*, No. 217, pp. 337–40.—By tables giving the results of tests on alumina and slag cements, L. shows that resistance to failure under load takes place at higher temperatures where the aggregate-cement ratio is high, but that there can not be less than 10% cement without too low a cold strength. The addition of calcined kyanite to the aggregate, increasing the mullite content, improved the refractory properties. Additions of chromite and magnesite were also found beneficial. Large quantities of silica added to the aggregate lowered the fusion point considerably, especially where much iron was present. The best alumina cement should have the composition 50 Al_2O_3, 10 SiO_2, and 40% CaO as shown by the phase-equilibrium diagram. Certain commercial cements closely approximate this composition. Continued heating at 1250° lowered the temperature of softening under load materially. See *Ceram. Abs.*, **17** [7] 253 (1938). V.D.F.

Vitreous china in the field of sanitary ceramics. A. STAERKER. *Ber. Deut. Keram. Ges.*, **18** [1] 11–24 (1937).—Until 1930, when vitreous earthenware from the U. S. was introduced, sanitary ware in Germany had been made either of fire clay or hard earthenware. A detailed comparison of the properties of these three materials is given. E.J.V.

Vitrified brick with a high grog content. V. A. RYBNIKOV AND P. P. ALIMOVA. *Keram. & Steklo*, **14** [4] 10–11 (1938).—Tests showed that vitrified grog brick has low apparent porosity (0.18 to 2.4%), low gas permeability (<0.01), high mechanical strength, incipient softening under load beginning at 1500° to 1600°, considerable shrinkage (5.3 to 6.3%), and low thermal stability. The firing temperature of these brick is somewhat below 1650°. M.V.C.

BULLETIN AND PREPRINT

Bauxite and aluminum. HERBERT A. FRANKE AND C. T. HERRING. Preprint from Bur. Mines Minerals Yearbook, 1938. 19 pp. Govt. Printing Office, Washington, D. C. Price 5¢. R.A.H.

Practical system for control of quality of fire clay. A. C. HUGHES. *Amer. Refrac. Inst. Tech. Bull.*, No. 70, 3 pp. (May, 1938).—The benefits of this system are summarized as follows: (1) By a more efficient method of clay selection at the source, a close approach to practical pretesting of lump material may be created. (2) A more complete knowledge of the character of the clay supply is provided. (3) Since type clays can be identified by all persons, responsibility for quality can be established more intelligently, and the clay can be checked at the mine, the plant, and the laboratory. (4) A better personal coöperation is established among mine foremen, plant superintendents, and laboratory representatives. (5) Improvements in quality and uniformity of the finished product are possible. H.E.S.

PATENTS

Alumina. AXEL S. BURMAN. Fr. 822,430, Dec. 30, 1937; *Chem. Abs.*, **32**, 4290 (1938).—Aluminous materials are treated with an acid, and the Al salt obtained is thermally dissociated into oxide and acid vapor. The powdered primary material, preferably calcined, is mixed with water and treated with hot-acid gases from the dissociation to form steam (which is recovered), a salt solution, and an insoluble residue (principally SiO_2). The solution produced is evaporated by the steam produced by the decomposition of the primary material to obtain a mass of crystallized Al salt. Apparatus is described.

Alumina production. R. B. DERR AND H. B. STERR (Aluminum Co. of America). U. S. 2,127,504, Aug. 23, 1938 (Dec. 18, 1935). The process of producing basic aluminum nitrate comprises concentrating a solution of aluminum nitrate, adding aqueous fluid while heating the solution to a substantially constant temperature until a substantial portion of the normal nitric acid content is removed, mixing the residue containing normal and basic aluminum nitrates with an aqueous solvent for normal aluminum nitrate selected from the group consisting of a solution of normal aluminum nitrate, a solution of normal and basic aluminum nitrates, and a solution of basic aluminum nitrate to form a solution in which at least a portion of the basic aluminum nitrate remains undissolved, and separating undissolved basic aluminum nitrate from the solution.

Bauxites. ROHSTOFFHANDEL DER VEREINIGTEN STAHLWERKE G.M.B.H. AND CLEMENS BETTENDORF. Fr. 822,335, Dec. 28, 1937; *Chem. Abs.*, **32**, 4292 (1938).—Fe compounds contained in bauxite are exposed, by means of fuel, to a reduction operation at a temperature at which the clay does not participate in any way in the reactions and at which the Fe formed is agglomerated as bloom, owing to a partial oxidation to slag of the gangue which adheres and to a reduction of the Fe compounds. The clay, the slag, and the bloom are separated from one another. A rotating trommel furnace which allows blowing of air or oxidizing gases into the slag-forming zone is used.

Glass blocks for troughs. HARTFORD-EMPIRE CO. Ger. 656,877, March 15, 1938; 80*b*. 8.07; *Chem. Abs.*, **32**, 4296 (1938).—The blocks are made from a composition containing mostly SiO_2 and Al_2O_3. Small quantities of TiO_2, Fe_2O_3, CaO, MgO, Na_2O, and K_2O may also be present.

Manufacturing fireproof blocks, etc., which can be used in glass trough furnaces or places handling molten glass. HARTFORD-EMPIRE CO. Ger. 661,269, May 19, 1938 (May 24, 1929); VI/80*b*. 8.07. Refractory blocks are made by grinding primary materials, low in fluxing substances and consisting mainly of silicon dioxide and alumina, to extreme fineness, calcining part of the ground material at a high temperature, mixing the pulverized calcined product with the rest of the original primary material, molding, and calcining this mixture at a high temperature. Primary materials are used which have a high silicon dioxide content and are low in fluxing substances so that (1) the final product has 60% SiO_2 and $1^1/_2$% (in all) of iron and alkali-metal oxides or 3% iron, alkali, or earth alkali-metal oxides; (2) the primary and secondary calcinings will result in the formation of a product consisting of only two constituents, which contain microscopic mullite crystals in a vitreous groundmass forming 40 to 75% of the entire amount, and (3) the

small amount of fluxing agent which was present and the SiO_2 which did not combine to form mullite are present as silicates. D.A.B.

Production of alumina. R. Englert and F. Becker. Ger. 661,174, May 19, 1938 (June 23, 1934); IV*b*/12*m*. 6. Aluminum silicates, such as kaolin and clay, are calcined at temperatures of 500° to 800°C with alkali compounds which readily split off their acid residues at these temperatures in the presence of silicates; the calcined product is dissolved in aqueous sulfurous acid, the solution is heated to 90°C in autoclaves, is cooled, and is worked up to alumina in the usual manner after separation of the precipitated silicon dioxide. D.A.B.

Refractory brick. Veitscher Magnesitwerke A.-G. Austrian 153,200, April 25, 1938; 80*d*.; *Chem. Abs.*, **32**, 6420 (1938).—Sintered or fused MgO is mixed with a powdered glass of high melting point, with or without Cr ore, corundum, or other refractory material, and the mixture is fired at a temperature above the melting point of the glass. The proportion of the glass may be up to 20%, and its composition is such that (*a*) the combined percentages of MgO, CaO, and one-third of the Al_2O_3, divided by the combined percentages of SiO_2 and two-thirds of the Al_2O_3, should be between 0.5 and 1.5, and (*b*) the ratio MgO: CaO should be more than 10 unless the glass contains small proportions of Ti and Mn, in which event the ratio MgO: CaO may be between 0 and 1. The glass may contain also small proportions of alkalis, P_2O_5, and B_2O_3 and may be taken in finer grain than the other refractory materials. Methods of procedure are indicated.

Refractory products and process of making. Corning Glass Works. Brit. 490,200, Aug. 24, 1938 (June 17, 1937).

Terra Cotta

Porcelain instead of metal. Kurt Draeger. *Vierjarsplan*, **2**, 139–41 (1938); abstracted in *Chem. Zentr.*, **1938, i**, 3959.—D. analyzes the possibilities of a partial replacement of metallic parts by porcelain, with special regard to different kinds of pipes and conduits. M.V.C.

PATENTS

Chimney pots. J. Johnson. Brit. 490,355, Aug. 24, 1938 (March 14, 1938).

Flue liner. Aaron Kauffmann. U. S. 2,128,463, Aug. 30, 1938 (June 8, 1936).

Producing a coating resembling terra sigillata on ceramic articles. Theodor Schumann (Schütte A.-G. für Tonindustrie). Ger. 660,928, May 12, 1938 (Feb. 26, 1937); VI/80*b*. 23.03. Addition to Ger. 626,112 (*Ceram. Abs.*, **15** [8] 249 (1936)).—Metallic oxides are allowed to act on the upper surfaces of ceramic articles, to which a clay suspension has been applied, during the firing process. D.A.B.

Whiteware

Adsorbed moisture films on the surface of glazed porcelain. F. W. Johnson. *Phil. Mag.*, **24** [163] 797–807 (1937).—J. gives experimental data which indicate that the leakage film on porcelain, if continuous, is made up of two components, one adsorbed and the other a surface solution. The proportional equilibrium between these two parts remains constant throughout the changes produced by voltage stress and changes of temperature. C.J.P.

Bushing flashovers reduced by porcelain umbrellas. A. H. Beiler. *Elec. World*, **109** [15] 1193 (1938).—Porcelain umbrellas mounted over the bushings of oil circuit breakers have been in service three years and have proved effective in protecting bushings from dust and moisture which cause flashovers. E.H.McC.

Cordierite gives low expansion in ceramic bodies. H. Thurnauer. *Ceram. Ind.*, **29** [5] 362–64 (1937).—Bodies of low thermal expansion can be obtained by developing cordierite crystals as the main ingredient of the fired body, the batch being composed as nearly as possible of $2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$. Such a body may consist of 39.6 talc, 47 clay, and 13.4% alumina but can also be made from magnesium carbonate, magnesium oxide, and aluminum hydroxide. The disadvantage of such bodies is their short vitrification range; the firing range is increased by the addition of 20 to 30% of zirconium oxide. The fired body then contains about 60% of cordierite crystals, the rest being mainly zirconium silicate crystals. The thermal shock properties and mechanical strength of the material are satisfactory. The difficulty of glazing cordierite bodies is mentioned. A new method, still in the experimental stage, consists in adding feldspar or other glassforming fluxes to a cordierite body. In this way vitrified materials are obtained with low thermal expansion and having a self-glaze on the surface. The increasing use of cordierite bodies in the electrical industry is pointed out. Vitrified bodies are also suited for use in the chemical industry. Artificial cordierite is used in preparing the body of the new material "Kemite" (*Ceram. Abs.*, **16** [10] 315 (1937)). E.J.V.

Electrical resistance of ceramic materials at temperatures up to 900°C. G. Pfestorf and E. F. Richter. *Physik. Z.*, **39** [4] 141–50 (1938).—In 1926 measurements were made on ceramic disks, tubes, etc., with shooped copper electrodes up to 400°C. Later, similar measurements (again with direct current) were made with samples having platinum electrodes. Appreciable differences were found with values obtained with rising and falling temperatures. These differences produce a loop in the resistance-temperature curve, as shown in several diagrams. It is caused by the specific property of each ceramic insulation material, as for alkaline electrical porcelain, alkali-free magnesia bodies, etc. Different types of metal electrodes such as platinum, nickel, silver, and carbon gave different results. While nickel and platinum show the same values, *i.e.*, a loop curve in heating up and cooling, silver behaved entirely differently. Only heavy silver layers gave satisfactory values; the thin coats corroded badly or disappeared entirely. In one case, the silver from the anode had traveled through the porcelain and was deposited as silver oxide upon the platinum (cathode) electrode and the surface of the porcelain on the other side. These results are similar to those formerly found for glass having silver electrodes. It is believed to be caused by migrating ions travelling in the direction of the cathode during electrolytic current transfer, if the anode material does not furnish additional ions to the insulation material. A close connection between the migration of the alkali ions and the described loop formation exists. Platinum electrodes do not release ions to the porcelain; nickel showed no electrolytic penetration of the porcelain. Alkali-free porcelains, magnesia porcelains, etc., show the same values of temperature resistance in heating up and cooling. The great differences found with alternating and direct currents do not allow comparisons between the resistance characteristics of insulation materials or application of results obtained with direct current to those obtained with alternating current. Tests were also made to show the duration resistance at 500°C for a porcelain material with 100 volts direct current. L.E.T.

Experimental glazes. L. Tontscheff. *Keram. Rundschau*, **46** [3] 25–26 (1938).—The conditions of tests are discussed. The milling requires reasonable speed, correct quantity of water, and an adequate weight of balls. After de-airing of the glaze and washing of the ceramic

body, six test pieces are fired in the usual kiln under normal conditions. Thin, average, and thick specimens of glazes must be tested. The manufacturing process of the body should also be considered. F.E.V.

Lead glazes and lead poisoning. H. LEHMANN AND M.-T. SCHULZE. *Keram. Rundschau*, **46** [9] 98–100 (1938).—Various frits, glazes, and lead silicates were exposed during 10 days to the action of stomachic liquid at 36° to 37°C. Glazes which have been used many years in the industry without inconvenience lose 0.015% of their lead contents in the liquid. The lead determination methods of Schmidt (electrolytic separation) and Behrens (dithizone) have been used. The test with 4% acetic acid is worthless. The maximum tolerable content in the blood is 0.06 mg. lead/100 cc. blood. F.E.V.

Structural changes in ceramic membranes. B. G. ZAPROMETOV AND K. KRUTIK. *Kolloid. Zhur.*, **3**, 523–35 (1937); abstracted in *Chem. Zentr.*, **1938, i**, 4095.—By measuring electrical conductivity of ceramic materials saturated with a KCl solution, the porosity of these materials was determined. Increase of the firing temperature of the material produced from kaolin lowers porosity in the temperature interval between 800° and 1300°. A great decrease of porosity, produced by the vitrification of kaolin, was observed at 1400°. M.V.C.

PATENTS

Ceramic dielectric material and process of making. WILLIAM DUBILIER AND JOSEF OPPENHEIMER. U. S. 2,128,289, Aug. 30, 1938 (Nov. 16, 1936). In a method of manufacturing a dense ceramic dielectric material, in particular adapted for electric condensers, having a dielectric constant exceeding 14 and containing at least one inorganic oxide of an element of the fourth group and at least one other inorganic oxide of an element selected from the second, third, or fourth group of the periodical system, the steps of shaping and presintering a finely divided, powdery mixture containing the oxides at a temperature substantially below its final sintering temperature, and thereupon compacting the mixture by heat treatment at least at sintering temperature in a selected atmosphere.

Cutting or dividing ceramic tubes, especially those made of porcelain. ROSENTHAL-ISOLATOREN, G.M.B.H. Ger. 655,083, Dec. 16, 1937 (Feb. 24, 1936); XII/80*d*. 4. A ring of yielding working material is pulled over the desired place of the tube, over this ring a high pressure is exerted, and the tube is simultaneously drilled until it divides at the predetermined place with a smooth break. D.A.B.

Flux distributing insulator. K. A. HAWLEY (Locke Insulator Corp.). U. S. 2,128,817, Aug. 30, 1938 (March 3, 1933).

Manufacture of ceramic products, especially ignition plug insulators. R. BOSCH AKT.-GES. Brit. 489,981, Aug. 17, 1938 (Dec. 1, 1936).

Manufacture of lead glazes. HANS-JOACHIM HARKORT. Ger. 660,527, May 5, 1938 (March 26, 1936); VI/80*b*. 23.03. Lead glazes are made by using primary materials containing lead sulfate, which are directly introduced into the frit batch; upon fritting, the lead sulfate is transformed to lead silicate. Readily oxidizing substances are used as decomposing agents for the $PbSO_4$, their premature oxidation by the oxygen of air being prevented until the transformation temperature of $PbSO_4$ is reached. D.A.B.

Spark plug. WILLIAM HARPER, JR. (H. B. Motor Corp.). U. S. 2,127,512, Aug. 23, 1938 (June 13, 1936). U. S. 2,127,513, Aug. 23, 1938 (May 25, 1937). JAMES GRANT. U. S. 2,129,003, Sept. 6, 1938 (Aug. 22, 1936).

Water closet. J. R. BEAM (Universal Sanitary Mfg. Co.). U. S. 2,129,398, Sept. 6, 1938 (Sept. 30, 1935).

Equipment and Apparatus

Application of dry mixing in the whiteware and refractories industries. F. A. FIX. *Bull. Amer. Ceram. Soc.*, **17** [9] 351–54 (1938).

Approved respirator. ANON. *Mill & Factory*, **22** [4] 126 (1938).—A respirator approved by the U. S. Bureau of Mines is described as giving protection against silica quartz, asbestos, aluminum, and ores in grinding, quarrying, and other industrial operations. It is lightweight, compact, comfortable, and has an effective surface of more than 30 sq. in. A metal cover prevents damage to the respirator by wearer's hands, surface dust, grease, oil, etc. D.A.B.

Artificial drying of brick. K. *Tonind.-Ztg.*, **62** [19] 216–18 (1938).—K. relates experiences with an artificial drier. As constructed and operated originally, it was not capable of drying 60,000 brick a day. The problem was solved by switching to steam power and using the waste heat of the boiler in addition to the waste heat of the kilns and by operating the drier room under plus pressure instead of minus pressure. W.K.

Batch mixing simplified by a traveling scale. ANON. *Mill & Factory*, **22** [2] 78 (1938).—Accuracy in weighing out batches of materials is insured by the use of a traveling scale. The method has been carried out with success in porcelain enamel smelters. A 150-ft. track is laid in a channel 6 ft. wide and deep, running along the route of materials. The materials are loaded into a hopper type container which is on the charging car. Material is added until the scale indicator reaches a determined point on the scale; the workman then presses a button, indicating this material, on the bank of buttons on the scale; the load is automatically recorded on permanent records locked within the scale, and the load is moved to the next point along the route. The foreman removes the record chart from the scale before the batch goes to the smelter and any mistakes can be rectified. A permanent record chart can be kept. D.A.B.

Cemented tungsten carbide alloys. W. P. SYKES. *A.I.M.M.E. Tech. Pub.*, No. 924; *Metals Tech.*, **5** [4] 11 pp. (1938).—S. gives detailed information on structures and physical properties as related to production methods and applications of the cemented carbides. F.P.P.

Colloidal fraction of milled material. A. H. M. ANDREASEN. *Ber. Deut. Keram. Ges.*, **19** [1] 23–29 (1938).—A. discusses the shapes of the particle-size distribution curves for materials subdivided by milling and crushing. A series of curves for the particle-size range 2 to 0.2μ shows the greater efficiency of small balls for wet milling. The distribution curve for the subdivision of quartz and porcelain by pure crushing is linear over the range 10 to 0.5μ. Illustrated. E.J.V.

Construction of alignment charts. R. MCADAM. *Colliery Guardian*, **156**, 114–16 (1938).—The use of alignment charts for recurring calculations is increasing rapidly, particularly because they can be used by anyone, irrespective of mathematical ability. Methods of construction and examples are given for alignment charts involving addition, subtraction, and multiplication. W.D.F.

De-airing pug mill. O. MANFRED. *Ber. Deut. Keram. Ges.*, **18** [1] 24–32 (1937).—M. summarizes recent developments in pug mills equipped with de-airing units. Illustrated. E.J.V.

Defects due to drying. KARL SPINGLER. *Ziegelwelt*, **69**, 56–58 (1938); abstracted in *Chem. Zentr.*, **1938, i**, 3676.—To eliminate injuries to brick during drying, the latter should be preheated without bringing about evaporation. This is obtained through the use of saturated hot air. In the second stage of drying, it is important that diffusion and the rate of evaporation are balanced. In general the cause of defective drying is poor mixing and working. M.V.C.

Determination of the circulating load in a wet closed-circuit grinding system. FRED C. BOND. *Mining &*

Met., **18** [371] 507 (1937).—Screen analyses are avoided by a method using the liquid-solid relationship. The circulating load in a wet-grinding mill in closed circuit with any type of classifier is given by $\frac{PF - C - DF}{D - S}$ tons /hr., where F is the feed tonnage to the mill, C is the new water added to the classifier, and P, S, and D are the dilution of classifier overflow, return sand, and mill discharge, respectively. E.J.V.

Efficiency of mechanical crushing processes. A. Smekal. *Chem. Fabrik*, **10**, 503–504 (1937).—The efficiencies of many mechanical crushing plants crushing materials such as quartz, limestone, cement, and coal are only 0.05 to 0.1%. Such installations are not regarded as uneconomical, for, in comparison with hand crushing methods, there is a great saving of time. E.P.

Examination of the macrostructure of materials and products with the help of X-rays: V. J. E. De Graaf. *Phillips Tech. Rev.*, **3** [6] 186–88 (1938).—The faults of assembly of X-ray tubes are shown with the aid of X-rays. By this method, it is possible to show breakdowns in cement due to bubbles which can not be shown by other methods. 6 illustrations. For Parts I–II see *Ceram. Abs.*, **17** [3] 118 (1938). H.K.R.

Expansion and shrinkage measurements on unfired ceramic bodies. W. Steger. *Ber. Deut. Keram. Ges.*, **19** [1] 2–22 (1938).—S. describes an apparatus developed for determining the expansion-shrinkage curve for the temperature range 100° to 1200°. Curves are presented for several clays and their mixtures with mica, sand, feldspar, limestone, magnesite, fluorspar, soapstone, and stoneware and hard porcelain bodies. The reactions which occur are revealed by the curves. Illustrated. E.J.V.

Flotation of fluorspar and quartz, a contribution to the flotation of polar nonmetallic minerals. A. Baumgarten. *Metall & Erz*, **35**, 314–17 (1938); *Chem. Abs.*, **32**, 6108 (1938).—If none or little heavy spar is present, fluorspar can be successfully floated to a high concentration. With greater quantities of heavy spar, a combination of gravity dressing followed by flotation is required. In the dressing of quartz sands and gangue quartz, the object is the removal of all Fe-bearing minerals. Flotation can accomplish this successfully.

Glass electrode for differential titration. Mladen Paič. *Compt. Rend.*, **207** [2] 151–53 (1938).—Glass electrodes as described by Cox were advantageously prepared from Corning glass 015 or Silichrome (neutral white glass), both of which can be joined easily with the interposing membrane between the two parts of the U-shaped electrode. An application is described. M.H.

Homogeneous clay preparation. Hielscher. *Tonind.-Ztg.*, **62** [6] 70 (1938).—H. briefly describes a new machine called a "sieve kneader" which kneads the clay and presses it through sieves. Illustrated. W.K.

Law of size distribution and statistical description of particulate materials. P. S. Roller. *Jour. Franklin Inst.*, **223** [5] 609–33 (1937).—R. gives a law of size distribution which relates weight per cent, y, and from this, frequency, to size of particle, x. This law is of the form $y = ax^{1/a}e^{-b/x}$, where a and b are constants. The two constants are easily determined on the basis of a linear functional relationship. The straight line obtained from this relationship is called the characteristic line. Occasionally, characteristics are obtained which are termed regressive and are concave or convex. The law has been found to hold for materials ground mechanically or reduced by physical or chemical means. Very good agreement was found for ceramic powders, cements, paint pigments, hydrated limes, soils, kaolins, and clays. The following physical constants of a powder can be found in terms of the two distribution constants: surface area per gram, number of particles per gram, and coefficient of uniformity. The advantages of applying the distribution law to experimental observations are discussed. C.J.P.

Measurement of dielectric losses and high-frequency conductivity: V, Low loss quartz condenser. P. Wulff, H. Schwindt, and S. Takashima. *Z. Physik. Chem.*, **39** [5–6] 315–21 (1938).—The construction of a quartz condenser with spun-up respectively inserted platinum plates is described. The instrument guarantees a good mounting of the condenser disks, without fusion of the metal, which can be closed airtight. The important viewpoint concerning its use as well as measures to suppress surface conductivity is discussed. 2 illustrations, 2 tables. L.E.T.

Measurement of particle size by the X-ray method. F. W. Jones. *Proc. Roy. Soc.* [London], **A166**, 16–42 (1938).—J. describes an experimental method which makes possible particle-size determinations with a standard cylindrical camera, any reasonable slit system or pinhole, and any convenient way of mounting the specimen. By mixing a suitable large-grained powder with the unknown, the uncertainties introduced by the experimental conditions can be eliminated. A.P.

Pipet apparatus for elutriation analysis. A. Neuberger. *Tonind.-Ztg.*, **62** [17] 190–91 (1938).—N. describes an improved pipet apparatus which is easier to manipulate, works faster, and is cheaper. W.K.

Precision weighing machine. Jeffrey Mfg. Co. *Steel*, **100**, 90 (May 10, 1937). H.E.S.

Production and some testing methods of metal powders. D. O. Noel, J. D. Shaw, and E. B. Gebert. *A.I.M.M.E. Tech. Pub.*, No. 928; *Metals Tech.*, **5** [4] 20 pp. (1938).—Production methods are described, and the uses for which powders are fitted when prepared by the various methods are discussed. Methods of testing density and particle-size distribution are reviewed in detail. F.P.P.

Purchase and inspection of tool steels. S. C. Spalding. *Metal Progress*, **33** [6] 601–605 (1938).—S. describes methods of setting up specifications and of performing the necessary tests. F.P.P.

Radiation pyrometer. Bristol Co. *Chem. Industries*, **42** [5] 540 (1938).—This radiation pyrometer records temperatures above 1000°F on a round or strip chart recorder. P.G.H.

Raw materials for tool and alloy steels as made in crucible, induction, and basic arc furnaces. H. C. Bigge. *Metal Progress*, **33** [5] 497 (1938).—B. gives a comprehensive tabulation of the composition of several types of refractories, pig iron, iron, alloy scrap, fluxes, ferro-alloys, and powdered deoxidizers for slag. F.P.P.

Recent developments in spray painting in pattern making. O. T. Koritnig. *Giesserei*, **25** [11] 293–99 (1938).—K. describes late designs of pumps and spray pistols and nozzles which make possible uniform pressure in spraying, which keep oil from the pump from getting into the spray, and which facilitate turning of the pistol in any desired direction, especially for spraying of molds and cores. M.H.

Rôle of heat-resisting alloys in short-cycle malleableizing furnaces. H. H. Harris. *Ind. Heating*, **5** [8] 683–86 (1938).—H. reviews and discusses Ni-Cr heat-resisting alloys for roller rails, skids, bearings, and trunnions and their selection. M.H.

Testing and working clays. Onni Dahl. *Sprechsaal*, **71** [10] 125–26 (1938).—D. points out the significance and importance of repeated examinations of clays during working with regard to their constant physical properties. M.V.C.

Tool steels, past and present. Induction furnace melting. H. C. Bigge. *Metal Progress*, **33** [5] 489–93 (1938).—B. discusses slag and flux compositions and ingot practice. F.P.P.

Types of metal powder products—a classification. G. J. Comstock. *A.I.M.M.E. Tech. Pub.*, No. 926; *Metals Tech.*, **5** [4] 10 pp. (1938).—The powder process is of great use for (1) manipulating highly refractory metals, such as W, Ta, and Mo, which can not be cast and formed in the usual melting and casting process; (2) circumventing some of the limitations of the melting and casting processes, even though they can be used; (3) forming aggregates in which the physical characteristics of the individual metallic components remain unchanged, such as cemented carbides; (4) achieving unusual structural

effects not otherwise obtainable, as in the graphite-bronze bearings made from powdered metals; and (5) producing products in substantially finished form that must be alloyed by dispersion or localized fusion, such as the Fe-Co-Ni magnet alloys. The principal commercial products now made from powders include refractory metals, hard cemented carbides, various types of bearings, and electrical contact materials. F.P.P.

BULLETINS

Bureau of Mines Haldane gas-analysis apparatus. L. B. BERGER AND H. H. SCHRENK. *Bur. Mines Information Circ.*, No. 7017, 24 pp. Free. The use, advantages, and disadvantages of a modification of the Haldane gas apparatus developed by the Bureau of Mines to permit determination of carbon dioxide, combustible gases, and oxygen are described. R.A.H.

Efficiency of impingers for collecting lead dust and fumes. J. B. LITTLEFIELD, FLORENCE L. FEICHT, AND H. H. SCHRENK. *U. S. Bur. Mines Repts. Investigations*, No. 3401, 9 pp. Free. The results obtained when using the midget impinger in collecting lead dust and fumes for chemical determination are given. See "Dust—," *Ceram. Abs.*, **17** [7] 258 (1938). R.A.H.

PATENTS

Centrifuge for optical determination of the size of small particles. I. G. FARBENIND. A.-G. Ger. 660,156, April 21, 1938 (March 27, 1936); IX/42*l*. 6.01. The liner containing the material to be analyzed is made of a material which is a good conductor of heat and which is well insulated against heat from the exterior. D.A.B.

Device for automatic coating of brick with engobe. JOSEF JACOBI. Ger. 660,927, May 12, 1938 (May 15, 1936); VI/80*a*. 58. A nozzle for spraying on and an air-pressure nozzle for distributing the engobe is arranged. D.A.B.

Device for drying ceramic objects. PORZELLANFABRIK KAHLA (Wilhelm Regerbis, inventor). Ger. 656,681, Feb. 11, 1938; 82*a*. 1.01; *Chem. Abs.*, **32**, 4299 (1938).

End liner for grinding mills. S. L. MILLER (American Ball-Mill Co.). U. S. 2,128,468, Aug. 30, 1938 (Sept. 9, 1935).

Giving ceramic material a coating of metal. STEATIT-MAGNESIA AKT.-GES. Brit. 490,232, Aug. 24, 1938 (Feb. 11, 1936); addition to 487,839.

Grinding machine. F. C. ATWOOD (Atlantic Research Associates, Inc.). U. S. 2,128,226, Aug. 30, 1938 (Feb. 1, 1932). A pair of grinding members having coöperating faces capable of maintaining a fluid-tight joint when pressed together.

Means for exfoliating vermiculite, etc. C. H. BUTLER (Amalgamated Minerals Corp.). U. S. 2,129,523, Sept. 6, 1938 (Dec. 17, 1936).

Method and apparatus for determining the temperatures of molten baths. W. E. SHENK AND B. M. LARSEN (United States Steel Corp.). U. S. 2,127,889, Aug. 23, 1938 (Nov. 30, 1935).

Method and apparatus for making lavatories, sinks, wash basins, etc. BRIGGS MFG. CO. Brit. 489,438, Aug. 10, 1938 (Jan. 27, 1936).

Mineral concentrator. ROBERT SMITH (R. S. Davis). U. S. 2,129,244, Sept. 6, 1938 (Oct. 24, 1936).

Treating raw clay materials. H. C. RAFETTO. U. S. 2,128,848, Aug. 30, 1938 (Oct. 3, 1936). The process of preparing raw clay material for manufacture into clay products consists in separating from the material the larger stones and foreign substances and breaking down the clay masses, separating the smaller clay-coated stones and solid particles from the broken-down residual material, and recovering the clay component of the tailings, consisting of the smaller stones and solid particles, by projecting the tailings into space by heavy impact, the impact first shattering and reducing the clay to finely divided condition and freeing the clay from the stones, and then separating the stones from the clay by effect of the differing inertias of the stone and finely divided clay particles.

Kilns, Furnaces, Fuels, and Combustion

Boiler furnace combustion chamber air inlet nozzles. K. CLEVE. *Feuerungstechnik*, **25**, 317–22 (1937).—C. studied the air distribution in a chamber setup by forcing air into the chamber through nozzles of different sizes and designs. For the same power consumption, the amount of turbulence was greater the larger the nozzle. The path of the secondary air in the combustion chamber of a water-tube boiler with a mechanical stoker was investigated. E.P.

Calculation of flame temperatures at constant pressure by the method of ΔT. L. REINGOLD. *Chaleur & Ind.*, No. 213, pp. 69–75 (1938).—The relation between heat of combustion, flame temperature, and specific heat of the products of combustion worked out by Le Chatelier for perfect combustion in a homogeneous mixture of gases at constant pressure neglects the effect of dissociation of the products of combustion and thus gives too high a value for the calculated flame temperature. R. shows that the correction for this dissociation is given by $\Delta T = \frac{\Delta Q}{I}$, where ΔQ is the absorption of energy by the dissociation and I is the specific heat of the gases. This is worked out to be $\Delta T = 10^3 \times 36.75 \frac{1.815y + 1.62t + s}{5.9\,aCO_2 + 3.8\,aH_2O + 8.7}$, where y = mol. of CO, t = mol. of H_2, and s = mol. of OH in the products of combustion from 1 mol. of undissociated combustion gases and aCO_2 = mol. of CO_2 and aH_2O = mol. of H_2O in 1 mol. of undissociated combustion gases. R. has plotted the values of ΔT in seven graphs covering the range of gas compositions with the use of which, by interpolation, ΔT may be readily obtained for any temperature. A further correction must be applied where excess air is used and may be read from a nomograph. The correction for dissociation is of greater importance at higher temperatures. There is an optimum amount of excess air for maximum temperature, which functions by preventing dissociation through the principle of mass action. V.D.F.

Calculation of flame temperature by the method of successive approximations. P. MONTAGNE. *Chaleur & Ind.*, No. 213, pp. 54–62 (1938).—The temperature developed by combustion to equilibrium in a homogeneous mixture of gases may be calculated by means of the equation: $Q - (T_c - t)\,C^{T_c} = 0$ (where Q is the heat of combustion, T_c is the flame temperature, t is the room temperature, and C^{T_c} is the mean specific heat of the mixture between the two temperatures). This requires that the state of equilibrium of the constituents be accurately known. The burning of hydrocarbons in air involves nine major constituents: H_2, H, O_2, O, H_2O, OH, CO_2, CO, and N_2. Thus a number of reactions are proceeding simultaneously. These reactions considered separately are classified as follows: (1) those in which biatomic molecules dissociate into atoms, *e.g.*, $H_2 = 2H$; (2) those between three constituents, *e.g.*, $2H_2O = 2H_2 + O_2$; and (3) those involving four constituents, *e.g.*, $CO_2 + H_2 = CO + H_2O$. For any given conditions of temperature and pressure the equilibrium of any one of these may be determined for any concentration of the constituents. A graphical method of solution for this determination is given, using a straight-line diagram for the first, a triangular one for the second, and a square one for the third. In a complex equilibrium, certain constituents are involved in several reactions. M. considers these in the order of their importance, calculating

the amount of a constituent tied up in the first for that reaction and obtaining the pressure of the system by a consideration of the partial pressures of the constituents and the temperature as the temperature of the whole. He then considers the next reaction, having corrected for the amounts of the common constituents tied up in the first. This process is continued and finally the whole series of reactions is recalculated; by these successive corrections, closer and closer approximation to the equilibrium conditions is obtained. From this and the use of tables of heats of combustion, Q and C^{Te} may be found and the flame temperature determined. This process is shortened by the use of graphical analysis for approximation. The results of such calculations show that the highest temperature may be obtained by using proportions of gases and oxygen other than the molecular ratios theoretically indicated for complete combustion. V.D.F.

Cost of electric firing of fine ware. A. RITTGEN. *Ceram. Ind.*, **29** [2] 126–30; [3] 198–200 (1937).—The earlier types of electric furnaces for fine ware were small laboratory and test devices, but large electric tunnels are now being used in regulation production in the Saar Basin. All the factors involved in the operation of electric kilns are considered, and economic advantages are claimed, owing to the small amount of kiln furniture required, the ease of control of temperatures, simplicity of manipulation, and fewer rejects. Making a comparison with a beehive kiln and a gas-fired tunnel kiln, the cost index of an electric kiln was little more than 50% of that of the other two types. Illustrated. E.J.V.

Developments in controlled atmosphere furnaces. ANON. *Ind. Heating*, **5** [3] 208–22, 234 (1938).—Furnace types are reviewed and described in which definite control is maintained over the chemical composition of the protective atmosphere to prevent scaling, decarburization, or tarnishing of the treated material. Partially burned hydrocarbon gases are now preferably used, being cheaper than pure N, H, or dried ammonia. Fuel-fired and electrically heated furnaces are described. M.H.

Fuel for firing brick. A. G. *Tonind.-Ztg.*, **62** [5] 53–54 (1938).—G. discusses the suitability of the ordinary fuels for firing brick and other products in annular kilns and recommends the use of an automatic stoker. W.K.

Gases for controlled atmospheres; requirements for purification. E. E. SLOWTER AND B. W. GONSER. *Metals & Alloys*, **9** [7] 163–68 (1938).—Work on controlled atmospheres is reviewed, and experiments are reported on the effect on C steels of small amounts of CO_2 and CH_4 in dried generator gases. F.P.P.

Liquefied gas for ceramic firing. E. A. JAMISON AND W. D. GERSTELL. *Ceram. Ind.*, **29** [6] 468–70 (1937).—Liquefied petroleum gases are available from oil refineries and natural gasoline plants. Industrial propane has an initial boiling point of −51°F and has a vapor pressure of approximately 122 lb. at 70°F. One gallon contains 91,800 B.t.u. and will gasify into approximately 36 cu. ft., 1 cu. ft. containing 2537 B.t.u. Hence this fuel has approximately five times the thermal value of manufactured gas and 2½ times that of the average natural gas. Liquefied petroleum gases are transported and stored in special tank trucks and storage tanks. Propane, producing a relatively small volume of products of combustion, lends itself to efficient tunnel kiln operation. Liquefied petroleum gas has a slow and uniform rate of flame propagation. Liquefied petroleum gases are being used for both continuous and batch-type glost and bisque kilns. Illustrated. E.J.V.

Losses in heating furnaces. M. NAUDET. *Chaleur & Ind.*, No. 217, pp. 333–36 (1938).—Heat loss as sensible heat in exit gases is inversely proportional to the CO_2 content and is represented by the expression $K \cdot \frac{T-t}{g}\%$, where t is the temperature of the entering air, T is the temperature of the stack gases, and g is their CO_2 content. The danger of incomplete combustion and consequent loss by the escape of CO limits the extent to which the CO_2 content may be increased, but by proper furnace construction, as high as 15% may be obtained consistently without trace of CO. N. gives figures to show that the CO_2 content is higher and the efficiency is consequently much better in mechanically stoked furnaces than in hand operated ones. Because of the greater quantity of air of combustion when the CO_2 is low, flame temperatures are lowered. The weight of issuing gases in this case is greater, but in the combustion zone the velocity of the gases is almost the same, since the temperature is lower. V.D.F.

Methods for estimating the grindability of coal. H. F. YANCEY AND M. R. GEER. *Amer. Inst. Mining Met. Engrs. Contrib.*, No. 94, 17 pp. (1936). W.D.F.

Mineral constituents of coal and their removal. H. SUSTMANN AND R. LEHNERT. *Brennstoff-Chemie*, **18** [18] 353–56 (1937).—The literature is reviewed under the classifications: (*a*) origin and nature of the mineral constituents; (*b*) their removal; (*c*) action of mineral acids on coal; (*d*) mode of combination of the inorganic constituents; (*e*) their behavior on combustion; (*f*) effect of chemical additions on the residual ash; and (*g*) importance of ash from coal. E.J.V.

More regular firing in batch kilns. J. GREWE. *Keram. Rundschau*, **46** [3] 26–27 (1938).—G. emphasizes the rapidity of temperature increase and the regularity of atmosphere characteristics. In the big quadrangular or round kilns, the lower central part has a more reducing atmosphere. Ceramic bodies with near sintering and melting points are difficult to fire, and substituting a solid fuel for another will not remedy this. G. gives examples of kilns with correct oxidizing conditions. Transformations of existing kilns must be studied in each particular case. F.E.V.

Progress of German electric furnace industry. A symposium. Development of electric arc furnaces. W. WILKE. *Elektrowärme*, **8** [7] 165–68 (1938). **Electric tunnel furnaces for the ceramic industry.** P. GATZKE. *Ibid.*, pp. 196–97.—G. describes furnaces for decor firing at 1300°C and up to 92 m. length. Energy consumption amounts to about 0.28 kw.-hr./kg. material for a one-track furnace. **Sheet enameling furnace, a high-capacity electric furnace.** H. MASUKOWITZ. *Ibid.*, pp. 198–201.—M. describes principles by which the material is heated directly by radiation only. Energy consumption was 370 kw.-hr./ton as compared with 504 kg. of coal per ton in a coal-fired furnace. **Recent electric furnaces for glass, ceramics, and enamel.** R. GRÄNZER. *Ibid.*, pp. 202–204.—G. describes new installations and gives comparison for temperature distribution and costs of older furnaces. M.H.

Temperature of open flames. W. T. DAVID. *Phil. Mag.*, **23** [153] 251–56 (1937).—A comparison is made between the sodium-line reversal method and the platinum wire method of measuring open flame temperatures. It is concluded that sodium in flame gases does not give true temperatures. The platinum method gives values which can be rationally correlated with mixture strength, but it is probable that they are overestimates of the true temperatures. C.J.P.

Tunnel kiln firing: I, Open flame *versus* muffle. B. J. MOORE. *Trans. Ceram. Soc.*, **37** [6] 241–53 (1938).—M. presents the advantages of the muffle kiln over the open or inflame kiln. R.A.H.

Variables in coal sampling. J. B. MORROW AND C. P. PROCTOR. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 645, 45 pp. (1935). W.D.F.

BULLETIN

Preparation of thin sections of coal. R. THIESSEN, GEORGE C. SPRUNK, AND H. J. O'DONNELL. *U. S. Bur. Mines Information Circ.*, No. 7021, 8 pp. Free. Detailed information is given concerning the preparation of polished blocks of coal for macroscopic examination and the making of thin sections for microscopic examination. R.A.H.

PATENTS

Extracting SO_2 from gases. IMPERIAL CHEMICAL INDUSTRIES, LTD. Ger. 661,552, May 25, 1938 (Oct. 5, 1935); IV*b*/12*i*. 21. Absorption of the SO_2 is brought about by means of salt solutions containing basic aluminum sulfate as an absorbent. D.A.B.

Tunnel kiln. L. L. LADD. U. S. 2,127,742, Aug. 23, 1938 (April 30, 1936).

Geology

Advances in the knowledge of the clay minerals. W. NOLL. *Ber. Deut. Keram. Ges.*, **19** [5] 176–205 (1938).—N. refers briefly to some problematical minerals (leverrierite, allophane) and to the synthesis of clay minerals. Many terms in the nomenclature have become superfluous, *e.g.*, smectite is montmorillonite, fuller's earth is bentonite, and *terre à foulon* is often used in the sense of montmorillonite. Many names in the nontronite group could be omitted, and the following minerals consist of kaolinite: pholerite (in part dickite), carnate, newtonite, Steinmark, microvermiculite, porcelain clay, porcelain earth, collyrite, arcilla, etc. E.J.V.

Bleach clay solubility. P. G. NUTTING. *Jour. Franklin Inst.*, **224** [3] 339–62 (1937).—The following varieties of bleach clays are distinguished by acid leach and oil bleach tests: (1) inactive and almost inactivable bentonite (Wyoming); (2) inactive but highly activable (Sanders, Westcliffe); (3) naturally active fuller's earth (Quincy); (4) artificially activated (Filtrol, Tonsil); and (5) active and further highly activable (Marianna). These all show the same lattice structure and no essential differences in refractive indices, thermal dehydration, or chemical composition; all are dominantly the mineral montmorillonite. The bleaching action is thought to be a surface effect on small molecular groups. The highest bleaching power is attained by rapid removal with moderately strong acid of about two-thirds of the bases of an activable bentonite. These are converted to fullers' earth by slow leaching in dilute acid and are not further activable. The solubilities of these five varieties of clay in acid and weak alkali solutions fail to reveal differences characteristic of their bleaching power, but the silica of active clays is apparently more soluble than that of inactive clays. All of these clays show pronounced maxima of silica solubility at low acid and alkali concentrations. These maxima are far higher than the solubility of fresh silica gel in water. Applications of these results are indicated. See "Technical—," *Ceram. Abs.*, **15** [1] 40 (1936). C.J.P.

Chemical analyses of porcelain earths and other ceramic raw materials. E. BUBLITZ. *Ber. Deut. Keram. Ges.*, **18** [10] 444–49 (1937).—B. gives analyses taken from the records of the Royal Porcelain Factory, Berlin. E.J.V.

Chemistry of clays: I, Behavior of dyes and of organic compounds forming colored salts on clay and related substances; II, Behavior of essential oils and their constituents on clay and related substances. HEINRICH CARLSOHN AND GERHARD MÜLLER. *Ber. Deut. Chem. Ges.*, **71B**, 858–63, 863–70 (1938).—The three important clay minerals, halloysite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O + 2H_2O$), kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$), and montmorillonite ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O + nH_2O$), are briefly discussed. As clays of the montmorillonite type are used for bleaching and decoloration purposes it is possible to study the behavior of the clay substance with dyes. The surface of the clay substance must be free from adsorbed material. Benzol and benzin are preferred as solvents. Water, alcohol, and similar easily adsorbable solvents must be avoided. Two organic dyes, both soluble in benzol and benzin, have been selected: Sudan red and benzanthrone (1% solution). Both are suitable for detecting clay substances with an acidlike structure. The color of benzanthrone (*o*-amino-azotoluol prepared with β-naphtha in alkaline solution) is golden yellow. The red dye solution was adsorbed without color change in nonacid substances such as Al_2O_3 and $CaCO_3$. Great differences were found with clays. Clays and natural bleaching earths show red color, while synthetic bleaching earths, containing mineral acids, adsorb the red reagent, show blue-violet, blue, and greenish blue colors dependent upon the water content, and give salts formation. The clay-acid complex loses its ability to form salts with the loss of the chemically combined water (700°C). Benzanthrone is advantageous with dark clays. Fluorescent colors formed in benzol solution with solid substances such as $CaCO_3$, Al_2O_3, and talc. The color was canary yellow. Natural bleaching earths showed bright green colors; synthetic bleaching earths (clay-acid complex) showed golden yellow to red-orange colors. Essential oils contain a number of unstable substances suitable for investigating the specific behavior of clays. A number are adsorbed without change, while others undergo reactions accompanied with rise in temperature. These may be used for the detection and recognition of catalytic actions (polymerization, ring formation, and water separation). Oil of turpentine and naphtha have been investigated with natural and synthetic bleaching earths. Natural earths should be used for the adsorption and reaction of essential oils without catalytic action. For the chemical conversion of essential oils and their components, synthetic bleaching earths should be used. L.E.T.

Clay minerals of California soils. W. P. KELLEY AND W. H. DORE. *Soil Sci. Soc. Amer. Proc.*, **II**, 115–20 (1937); *Chem. Abs.*, **32**, 5977 (1938).—X-ray diffraction patterns obtained at ordinary temperatures and after heating to 500° can be used to distinguish between the montmorillonitic and the kaolinitic classes of minerals. Heating above 600° destroys the patterns of the clay minerals but not of quartz and minerals related to micas. Only one type of clay mineral is usually found in the colloid from a soil series. There is no definite relation between type of clay mineral and base-exchange capacity. Exchangeable cations are not located between layers of the crystal lattice. Both the parent material and the conditions of weathering are important in determining the type of clay mineral formed. The SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios are of doubtful significance in classifying soil colloids. High ratios are usually associated with high exchange capacities. The base-exchange capacity is not necessarily determined by the kind of clay mineral but is greatly influenced by the particle size.

Constitution of clays. DEM. *Argile*, No. 182, pp. 19–23 (1938).—D. discusses the theories of G. E. Ekblaw and R. E. Grim, American geologists, on the constitution of clays. M.V.C.

Crystalline structure and decomposability of Greek bauxite. A. A. DELYANNIS AND K. ALEXOPOULOS. *Metall & Erz*, **34**, 476–77 (1937); *Chem. Abs.*, **32**, 5727 (1938).—The Al_2O_3 readily soluble in hot aqueous NaOH is present as boehmite, whereas that insoluble is present as diaspore.

Investigations on clay minerals. G. KEPPELER. *Ber. Deut. Keram. Ges.*, **19** [5] 159–76 (1938).—The X-radiogram is the surest means of determining the principal properties of a clay mineral or a clay. If small quantities of impurities are present, especially in a very finely dispersed state, they are not revealed in the X-ray diagram; they may, however, greatly influence the properties of a clay. Comparison of the water content in the green state, the loss of water on heating, its reversibility, the thixotropy, and the surface properties of some important clay minerals and clays shows that, by careful observation of these properties, it is possible to demonstrate the presence of impurities which are not shown by the X-ray diagram. It is probable that the ceramic clay known as "Kärlichen Blauton" contains montmorillonite in addition to kaolinite, although the X-ray diagram shows it as a pure kaolinite clay. E.J.V.

Metastable γ-Fe_2O_3 phase in several samples of mag-

netite in process of transfc.mation. V. MONTORO. *Metallurgia Ital.*, **30** [5] 231–34 (1938).—X-ray measurements established the presence of the metastable γ-Fe_2O_3 phase accompanying the Fe_3O_4 phase in several samples of polarized magnetite from Elba. γ-Fe_2O_3 tends to transform rapidly to α-Fe_2O_3 at 600°C. The presence of this metastable phase probably accounts for the characteristically superior ability of Elba magnetite to retain its magnetism, as γ-Fe_2O_3 has been shown to possess a higher coercive force than ordinary magnetite. F.P.P.

Nepheline syenite from Ontario. HUGH S. SPENCE. *A.I.M.M.E. Tech. Pub.*, No. 951; *Mining Tech.*, **2** [4] 9 pp. (1938); see *Ceram. Abs.*, **17** [1] 38; [7] 262 (1938). W.D.F.

Problem of deferment in the valuation of mineral properties. F. B. CLARK. *Colliery Guardian*, **156**, 1002–1003 (1938).—C. gives four methods for the valuation of two different mineral properties, one being mined now and mining on the second being delayed until the first is finished. W.D.F.

Recovery of selenium and tellurium at Copper Cliff, Ontario. FREDERIC BENARD. *A.I.M.M.E. Tech. Pub.*, No. 908; *Metals Tech.*, **5** [2] 9 pp. (1938).—B. describes a new plant and process for recovering Se and Te; the previous process was described in *Trans. Amer. Inst. Mining Met. Engrs.*, **106**, 391 (1933). The Se process consists in removing base metals and Te from the feed solutions by neutralizing and then filter pressing the neutral solution. The resultant press sludge comprises the feed to the Te plant, while the effluent is charged in batches to precipitators where the Se is precipitated by gassing with SO_2. The granular product is water washed, pulverized, dried, and screened; it analyzes 99.70 Se, 0.12 Te, 0.13 ash, 0.001 Cu, and 0.01% Fe. The crude Te sludge from the Se process is charged to a dissolving tank, suspended in H_2O, treated with caustic to dissolve the tellurium oxide, and filtered. The filtrate (sodium tellurite) is neutralized with sulfuric acid, and the impure precipitate of tellurium oxide is settled, washed, redissolved in caustic, and heated with sodium sulfide to precipitate the Pb. After the solution is filtered, pure tellurium oxide is reprecipitated in a neutralizing tank; this is settled, washed, and rolled to a powder. The oxide is reduced to metal by mixing with flour and borax and heating in a covered crucible in a tilting furnace. The molten metal is cast in a slag-protected iron mold. The product analyzes Te 99.75%, Se 0.04%, and Pb trace. F.P.P.

Relations between the crystal structure of minerals and their base-exchange capacity. C. H. EDELMAN. *Trans. Internat. Congr. Soil Sci., 3rd Congr., Oxford, 1935*, **3**, 97–99 (1935); *Chem. Abs.*, **32**, 5728 (1938).—The cleavage surfaces of halloysite have the following possible configurations: (I) a sheet of O ions bound to Si; (II) a sheet of OH ions bound to Al; and (III) a sheet of OH ions bound to Si. I and II are possible for kaolinite, which has slight exchange activity (no more than might be caused by unbalanced valences at the edges of the cleavage planes) from which it is concluded that III is the cause of the strong exchange properties of halloysite. Muscovite has moderate exchange capacity; its structure is a complex of layers $Al_2(AlSi_3)O_{10}(OH)_2$, strongly bound by common O ions and linked by K ions in 12-fold position and completely regular in distribution. This is not true of the Al in the tetrahedron layers; its distribution is statistical, so that the K ions attached to the cleavage faces are not equivalent; some have $^1/_3$ of their negative free valency, and wherever these predominate, that spot, as well as the edges of the planes, is more favorable for exchange. The strong exchange capacity of montmorillonite can not be explained on these bases if Hofmann's structure for this mineral is correct, and for this reason the latter may be subject to revision.

Special methods for concentrating and purifying industrial minerals. G. W. JARMAN, JR. *A.I.M.M.E. Tech. Pub.*, No. 959; *Mining Tech.*, **2** [4] 10 pp. (1938).—For best results all material should be sized. An induction magnetic separator deflects magnetic material across a knife-edge. This separates iron-bearing materials from feldspar, kyanite, kernite, fire clay, and glass sand; apatite from nelsonite; and zircon from beach sand. A Frantz isodynamic magnetic separator has been developed in the laboratory which separates zircon from rutile and silica, scheelite from pyrite and galena, mica from quartz, etc. An air flotation table resembles an ordinary wet concentrating table and has a much greater tonnage. It separates a mixture of scheelite, pyrite, and galena from the gangue in a tungsten ore, rutile from zircon, pyrrhotite from actinolite, metal particles from oxides in a lead-tin dross, and flat or spiky pieces from cubical or round pieces of the same material. An improved electrostatic separator removes quartz from fluorspar, feldspar, nepheline syenite, etc.; rutile from zircon; and mica from graphite. These methods do not always work well on −100-mesh material. The Frantz Ferro filter removes iron bearing particles of the order of 5 microns from suspensions in clays, slips, enamels, and fluorspar flotation concentrates. W.D.F.

White-firing Schletta pitchstone kaolins and clays. A. LAUBENHEIMER AND H. LEHMANN. *Ber. Deut. Keram. Ges.*, **18** [12] 531–38 (1937).—A comparison of the nature and properties of the Schletta clays with those of Kemmlitz and Löthain kaolins is made, with special reference to the parent rocks (pitchstone and Rochlitz and Dobritz quartz porphyries). A description of complete physical, chemical, and ceramic examinations is presented. Illustrated. E.J.V.

BOOKS AND BULLETINS

Clays: kaolin (china clay and paper clay), ball clay, fire clay, bentonite, fuller's earth (bleaching clays), and miscellaneous clay. PAUL M. TYLER AND R. W. METCALF. Reprint from U. S. Bur. Mines Minerals Yearbook, 1938. Supt. of Documents, Govt. Printing Office, Washington, D. C. 14 pp. Price 5¢. R.A.H.

Concentration of low-grade magnesite ores by flotation. H. A. DOERNER AND DWIGHT L. HARRIS. Coöperative publication of the U. S. Bur. Mines and the State College of Washington. 30 pp. Price 25¢. Mining Expt. Sta. and State Electrometallurgical Lab., Pullman, Washington. R.A.H.

Field Tests for Minerals. E. H. DAVISON. Chemical Publishing Co., New York. 60 pp. Price $3.00. Reviewed in *Science News Letter*, **33** [12] 192 (1938).—The book is useful to the student of mineralogy and is also valuable as a reference to the practicing mineralogist. P.G.H.

Fluorspar Industry of the United States with Special Reference to the Illinois-Kentucky District. PAUL HATMAKER AND HUBERT W. DAVIS. Coöperative publication of the U. S. Bur. Mines and the Illinois Geological Survey, Urbana, Ill. *Illinois State Geol. Survey Bull.*, No. 59, 128 pp. Price 50¢. R.A.H.

Geology of the Wigan District. ANON. *Geol. Survey Gt. Brit., Mem.*, **1938.** H. M. Stationery Office, London. Price 5s. The geology of the area around Wigan is described. It is chiefly occupied by Coal Measure rocks (Lower Series), part of these being overlain by Boulder clay. The chief ceramic materials are valuable fire clays, brick clays, hydraulic limestone, and glass sand. The chief locations of these are clearly stated. There is a lengthy geological bibliography. A.B.S.

Gypsum, Anhydrite, Celestine, and Strontianite. ANON. *Geol. Survey Gt. Brit., Special Repts. Mineral Resources Gt. Brit.*, **3.** H. M. Stationery Office, London. 3d ed. 100 pp. Price 2s 6d. The occurrence, composition, properties, and uses of gypsum, anhydrite, celestine, and strontianite in Great Britain are described. A.B.S.

Industrial Minerals and Rocks (Nonmetallics Other Than Fuels). Edited by SAMUEL H. DOLBEAR, Chairman, Committee on the Industrial Minerals Volume, American Institute of Mining and Metallurgical Engineers. Maple Press Co., York, Pa. 955 pp. Price $6.00. The chapters are as follows: Abrasives, by V. L. Eardley-Wilmot, pp. 1–58. Sillimanite group—andalusite, kyanite, sillimanite, dumortierite, by P. F. Kerr, pp. 59–74. Asbestos,

by J. G. Ross and G. F. Jenkyns, pp. 75–96. Barium minerals, by W. M. Weigel, pp. 97–110. Bauxite, by E. C. Harder, pp. 111–28. Bentonite, by Paul Bechtner, pp. 129–34. Bleaching clay, by J. W. Bell and S. R. Funsten, pp. 135–48. Borax and borates, by W. T. Schaller, pp. 149–62. Cement materials, by B. L. Miller, pp. 163–90. Chalk, by Hewitt Wilson, pp. 191–98. Chromite, by G. E. Seil, pp. 199–206. Clay, by H. Ries, pp. 207–42. Diatomite, by A. B. Cummins and Henry Mulryan, pp. 243–60. Feldspar, by B. C. Burgess, pp. 261–82. Fluorspar and cryolite, by E. F. Burchard, pp. 283–302. Precious stones, by S. H. Ball, pp. 303–32. Graphite, by B. L. Miller, pp. 333–46. Granules, by H. H. Hughes, pp. 347–52. Gypsum, by D. H. Newland and H. J. Brown, pp. 353–74. Heat and sound insulators, J. E. Lamar and C. F. Fryling, pp. 375–88. Iceland spar and other crystals of related use, by H. H. Hughes, pp. 389–94. Lime, by Paul Hatmaker, pp. 395–426. Lithium minerals, by W. T. Schaller, pp. 427–32. Magnesite, by R. E. Birch, pp. 433–48. Manganese, by G. H. Chambers, pp. 449–54. Mica, by H. S. Spence, pp. 455–82. Mineral fillers, by A. H. Emery, pp. 483–92. Mineral pigments, by Hewitt Wilson, pp. 493–504. Minor industrial minerals, by P. M. Tyler, pp. 505–22. Monazite, by F. L. Hess, pp. 523–26. Native bitumens, by A. H. Redfield, pp. 527–32. Nitrates, by H. R. Graham, pp. 533–42. Phosphate rock, by H. S. Martin and James Wilding, pp. 543–70. Potash, by H. I. Smith, pp. 571–600. Pumice and pumicite, by B. N. Moore, pp. 601–608. Refractories, by P. M. Tyler and R. P. Heuer, pp. 609–42. Salt, by W. C. Phalen, pp. 643–70. Sand and gravel, by J. R. Thoenen, pp. 671–720. Slate, by C. H. Behre, Jr., pp. 721–38. Sodium carbonate and sodium sulfate, by R. C. Wells, pp. 739–48. Special sands, by H. Ries, pp. 749–62. Dimension stone, by Oliver Bowles, pp. 763–94. Crushed and broken stone, by S. B. Patterson, pp. 795–836. Strontium minerals, by B. N. Moore, pp. 837–44. Sulfur and pyrites, by W. T. Lundy, pp. 845–72. Talc, soapstone, and pyrophyllite, by J. L. Gillson, pp. 873–92. Titanium, by F. L. Hess and J. L. Gillson, pp. 893–910. Tripoli, by C. E. Heinz, pp. 911–22. Index, pp. 923–55. Each chapter has a bibliography. This is a very comprehensive book.
W. D. FOSTER

Mineral Physics Studies. Metallurgical Division Progress Report No. 3. *U. S. Bur. Mines Repts. Investigations*, No. 3400, 85 pp. Free. The following papers are included: **Physicochemical nature of metallic interfaces.** R. S. DEAN. **Development and application of the coercimeter.** V. H. GOTTSCHALK. **Construction and operation of a magnetic balance.** F. S. WARTMAN. **Coercive force of rods deformed by torsion.** E. V. POTTER. **Sonic flocculator as a fume settler; theory and practice.** H. W. ST. CLAIR. **Effect of lattice discontinuities on the magnetic properties of magnetite.** DAVID JAY DOAN.
R.A.H.

Minerals Yearbook, 1938. U. S. BUREAU OF MINES. Supt. of Documents, Govt. Printing Office, Washington, D. C. 1339 pp. Price $2.00. This edition presents a complete economic and statistical summary of the mineral industry of the United States in 1937 and contains a larger amount of precise and detailed data than any previous edition.
R. A. HEINDL

Minor nonmetals, carbon dioxide, graphite, greensand, kyanite, lithium minerals, meerschaum, mineral wool, monazite, olivine, strontium minerals, and vermiculite. PAUL M. TYLER. Preprint from U. S. Bur. Mines Minerals Yearbook, 1938. 16 pp. Price 5¢. Govt. Printing Office, Washington, D. C.
R.A.H.

Talc, pyrophyllite, and ground soapstone. BERTRAND L. JOHNSON AND K. G. WARNER. Reprint from U. S. Bur. Mines Minerals Yearbook, 1938. 8 pp. Price 5¢.
R.A.H.

PATENT

Separating brookite and rutile from zircon and obtaining titanium oxide therefrom. C. J. KINZIE AND EUGENE WAINER (Titanium Alloy Mfg. Co.). U. S. 2,127,664, Aug. 23, 1938 (Aug. 29, 1936). The method of separating an intimate and commingled mixture composed substantially of industrially inseparable grains of titanium oxide minerals and zircon comprises heating the mixture in the presence of from 5 to 25 parts of carbon per 100 parts of the ore mixture under reducing conditions at temperatures below 1600°C but sufficiently high to form a titanium-oxygen-carbon complex from the titanium oxide minerals without altering the zircon grains, then calcining the cooled charge under oxidizing conditions to remove carbon from the complex, and separating the synthetic titanium oxide material from the zircon.

Chemistry and Physics

Analysis of technical products derived from the working up of bauxite. U. PELAGATTI. *Chimica & Industria*, **20** [2] 75–76 (1938).—To make the best use possible of the residual slime of bauxite workings, a method was developed to determine rapidly its content of Fe_2O_3, TiO_2, and Al_2O_3. The total content of these three constituents is first determined by melting a 1-g. sample in a platinum crucible with 10 parts of bisulfate of potassium and then determining the individual parts by any known method. The procedure is described in detail.
M.H.

Colloidal properties of clay suspensions and gels. CHARLES E. REED. *Trans. Amer. Inst. Mining Met. Engrs.*, **127**, 240–62 (1938); see *Ceram. Abs.*, **17** [6] 229 (1938).
W.D.F.

Comparisons of nondestructive material testing by X-ray shadow pictures and by magnetic testing. M. v. SCHWARZ. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben*, **86** [7] 189–93 (1938).—Both methods are critically discussed and examples are given in photographs. The magnetic method is considered superior to the X-ray method in testing material for cracks, as even very fine ones can be more readily detected by the deviation of the magnetic lines of force. Apparatus is described.
M.H.

Equilibrium diagrams of the three binary systems (1) $CaO{\cdot}SiO_2$–TiO_2–$MgO{\cdot}TiO_2$, (2) $CaO{\cdot}MgO{\cdot}2SiO_2$–$MnO$–$TiO_2$, and (3) $CaO{\cdot}SiO_2$–$2CaO{\cdot}Fe_2O_3$. KEIZO IWASE AND USABURO NISIOKA. *Science Repts. Tôhoku Imp. Univ., Series 1*, **26** [4] 592–601 (1938).—Quenched specimens were studied with a metallurgical microscope, and (3) was also studied by thermal analysis. These three systems are all of the simple eutectic type with no solid solution. The eutectics are as follows: (1) at 1305°C and 32% $MgO{\cdot}TiO_2$, (2) at 1183°C and 48% $MnO{\cdot}TiO_2$, and (3) at 1183°C and 45% $CaO{\cdot}SiO_2$.
W.D.F.

Fractionation of a clay into closely monodispersed systems. F. H. NORTON AND S. SPEIL. *Jour. Amer. Ceram. Soc.*, **21** [10] 367–70 (1938).

High-frequency technique. KURT KRÜGER. *Physik*, **6** [3] 1–26 (1938).—The entire literature referring to high-frequency technique is reviewed. K. deals with ceramic and a few other construction materials and gives dielectric constants (k) and loss factors (pf) for the following materials: fused quartz k 4.5, pf 1.0^{-4}; Bakelite k 5.0, pf 220^{-4}; steatite k 6.4, pf 15–20^{-4}; steatite, special, k 6.5, pf 2.6 to 3.4^{-4}; titanium bodies k 40 to 50, pf 5 to 10^{-4}; titanium bodies, common, k 80 to 100, pf 20 to 40^{-4}. The above values are between 10^6 and 10^9 cycles. 200 references.
L.E.T.

Investigation of the thermal behavior of alkaline-earth carbonates by the emanation method: I, Monotropic conversion of calcium carbonate. K. E. ZIMENS. *Z. Physik. Chem.*, **37** [3–4] 231–40 (1937).—Z. discusses the principle, application, and procedure of O. Hahn's emanation method. The determination of the emanating ability (EmV) is described and a simple formula for its calcula-

tion is given by the "Stroemungsmethode" (flowing method). The results obtained with the emanation method on heating of precipitated calcite and aragonite material are as follows: (1) the monotropic conversion of aragonite into calcite is shown very well with the emanation method; the results of the *EmV* curves are confirmed by X-ray; (2) the speed of conversion is noticeably high above 450°C; with a rate of heating of 6°/min., the converted relative amount is largest at 510°C; at a rate of 12°/min. it is largest at 530°C; (3) the dissociation temperature of the precipitated calcium carbonate at atmospheric pressure was 910°C. **II, Barium carbonate and strontium carbonate. Enantiotropic transformation.** *Ibid.*, pp. 241–59.—Changes in the structure of barium carbonate and strontium carbonate on heating up to 1400°C have been studied by the emanation method. The essential influence of impurities and grain size upon the thermal behavior is shown. The conversion temperature of the rhombic into the hexagonal for $BaCO_3$ is 810°C and for $SrCO_3$ it is 925°C. 8 heating curves. L.E.T.

Oxyhalides of silicon. H. Reinboldt and W. Wisfeld. *Ann. Chem.*, **517,** 197–211 (1935).—A review of oxyhalide compounds of silicon is given, and the method of preparation and properties of three newly isolated compounds, $Si_4O_4Cl_8$, Si_2OBr_6, and $Si_4O_4Br_8$, are described. D.A.B.

Photographic principles of material testing with X-rays. J. Eggert. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben,* **86** [7] 174–81 (1938).—Photographing with direct and secondary X-ray radiation is discussed and described in general and is compared with exposures to ordinary light. The evaluation of the films is explained. 11 references. M.H.

Practice of statistics. Measurement of dissimilarities of distribution. C. Boehm. *Chem. Fabrik,* **11,** 65–74 (1938).—B. compared different methods of assessing distribution, *i.e.*, arithmetic mean, mean deviation, upper and lower limits, and methods based on statistical theory, in the case of three sets of measurements of the tensile strength of alloys. Safe conclusions could be based only on theoretical statistical methods which took account of the number of specimens in each batch. E.P.

Principles and applications of measuring strains by X-rays. R. Glocker. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben,* **86** [6] 147–48 (1938). M.H.

Quantitative separation of metals by hydrogen sulfide: I, Quantitative separation of zinc from nickel by hydrogen sulfide. Hisaji Kato. *Science Repts. Tôhoku Imp. Univ., Series 1,* **26** [4] 714–32 (1938).—Zinc may be completely precipitated at a p_H greater than 1, while nickel is not precipitated until about p_H 3. The most suitable p_H for these separations is 2.40. Enough of a monochloroacetic acid-sodium monochloroacetate buffer should be used to neutralize the acid from the precipitation. The induced precipitation of nickel sulfide should be avoided by using a clean smooth vessel, passing in hydrogen sulfide (rapidly at first), working at room temperature, and letting the precipitate stand. **II, Quantitative separation of zinc from cobalt by hydrogen sulfide and the mechanism of precipitation of nickel and cobalt sulfides.** *Ibid.*, pp. 733–42.—The p_H is buffered at 2.3 with monochloroacetic acid and sodium monochloroacetate. Hydrogen sulfide is then passed in, and the zinc is completely precipitated while the cobalt remains in solution. Both nickel sulfide and cobalt sulfide have an unstable, more easily precipitated form which changes to the stable form on standing. W.D.F.

Relation between coarse structure and static strength of welds. E. A. W. Müller. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben,* **86** [6] 152–54 (1938).—M. compares exposures taken under different mechanical stresses and points out the defects. M.H.

Relations between silicates and sulfides. A. S. Ginzberg. *Trudy Petrograf. Inst. Akad. Nauk S.S.S.R.,* **4,** 21–44 (1933); *Chem. Abs.,* **32,** 4418 (1938).—The systems Fe_2SiO_4–FeS, $MnSiO_3$–FeS, and Mn_2SiO_4–FeS were examined. Rapid cooling results in a gravitational separation of silicate and sulfide in two immiscible layers, and slow cooling results in a crystalline eutectic structure of the two portions.

Theory of diffusion in solids. John E. Dorn and Oscar E. Harder. *Trans. Amer. Inst. Mining Met. Engrs.,* **128,** 156–84 (1938).—A discussion is included. See *Ceram. Abs.,* **17** [6] 234 (1938). W.D.F.

Transfer of silica in gaseous form. D. S. Belyankin and A. M. Vinogradova. *Trudy Petrograf. Inst. Akad. Nauk S.S.S.R.,* No. 7–8, pp. 5–6 (1936); *Neues Jahrb. Mineral. Geol.,* Referate II, 391–92 (1937); *Chem. Abs.,* **32,** 6181 (1938).—A felt-like coating of amorphous SiO_2 was found on the surface of a ceramic mass made from Latninski clay (48% SiO_2) and sawdust (15 to 20%) heated at 1350°. The coating consisted of fine isotropic hairs 0.003 mm. thick. Their formation is attributed to transportation of SiO_2 from the clay by H_2O vapor from the sawdust.

Two-dimensional crystals of silica. N. A. Shishakov. *Acta Physicochim. U.R.S.S.,* **7,** 727–36 (1937); see *Ceram. Abs.,* **17** [5] 200 (1938). E.P.

Viscosity of slags in the silica–lime–ferrous oxide system. B. P. Selivanov and V. M. Shpeizman. *Metallurg,* **12** [6] 7–10 (1937); *Chem. Abs.,* **32,** 4116 (1938).—The viscosities of 19 slags containing SiO_2 25.0 to 49.5, CaO 0 to 49.6, and FeO 17.8 to 75.0% were determined between 1200° and 1400°.

X-ray densography. M. v. Schwarz. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben,* **86** [6] 154–56 (1938).—S. explains how the density or blackening of the X-ray exposure can be used for examining the soundness of a work piece. The density of the blackened exposure is measured by a photoelectric arrangement. The procedure is described in detail. M.H.

X-ray examination as tool in iron and steel research. W. Schmidt and E. H. Schulz. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben,* **86** [7] 161–66 (1938).—Principles and methods are discussed according to their use for coarse or fine structure examination or spectrum analysis. X-ray spectrum analysis has proved valuable for structure determinations at high temperatures; examples for Cr_2O_3 and Al_2O_3 in steels and $MgCO_3$, MgO, and MgO-FeO in refractories are described at length on the basis of the respective equilibrium diagrams. X-ray spectrum analysis fails only when looking for elements from H (1) to Na (9) of the periodic system, as their determination by this method is difficult or impossible, and when the elements to be analyzed amount to less than 0.01%. 7 references. M.H.

X-ray investigations of the binary systems TiO_2–MgO, ZrO_2–MgO, and ZrO_2–TiO_2. W. Büssem, C. Schusterius, and A. Ungewiss. *Ber. Deut. Keram. Ges.,* **18** [10] 433–43 (1937).—Reference is made to previous work on the dielectrical properties of mixtures of the three oxides MgO, TiO_2, and ZrO_2 (*Ceram. Abs.,* **16** [1] 26 (1937)). Two new dielectrics have recently been developed, one consisting mainly of magnesium titanate and having a dielectric constant of about 15, independent of temperature, and the other having a much higher constant (up to $\epsilon = 70$) but being dependent on temperature. The latter shows low dielectric loss for both high and low frequencies and consists of mixtures of titanium dioxide and zirconium dioxide. X-ray investigations were carried out on the above three binary systems, using the Debye-Scherrer method with a chamber of 57.3 mm. diameter and Cu-K rays. The raw materials used were of "technical purity" and were wet ground in steatite mills for 15 hr. in the calculated proportions, dried, and pressed into disks about 15 mm. in diameter, without use of oil or water. These disks were fired in gas furnaces to cone 16 (about 1460°) in 8 hr. After cooling, the disks were finely ground and the powder was used to obtain the X-radiograms. Data obtained are presented in tabular form and are discussed in detail. E.J.V.

X-ray picture of the coarse structure and endurance strength. H. Moller. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben,* **86** [6] 148–52 (1938).—M.

explains, by examples, the evaluation and interpretation of exposures. 8 references. M.H.

X-rays as means for research in metallography. W. KOSTER. *Berg- & Hüttenmänn. Monatsh. Montan. Hochschule Leoben*, **86** [6] 145–47 (1938).—K. explains the principles and compares this method with others. M.H.

PATENTS

Device for automatic gas analysis with different measuring ranges. CARL A. HARTUNG. Ger. 655,601, Dec. 30, 1937 (Nov. 12, 1935); IX/42*l*. 4.04. Several burets, connected in parallel and measuring and intercepting the gas before analysis, are used, and automatically or by hand the gas mixture to be analyzed is conducted into all or a few of the burets and the others are filled with suitable neutral or reaction gas upon changing the range of measuring. D.A.B.

Double silicates of zirconium and methods of making. C. J. KINZIE (Titanium Alloy Mfg. Co.). U. S. 2,127,844, Aug. 23, 1938 (June 12, 1934). The method of making a double silicate of zirconium consists in heating a charge composed of finely milled zirconium silicate and zinc oxide at temperatures below fusion but sufficiently high to secure a substantially complete reaction and decomposition of the zirconium silicate to form a zinc zirconium silicate ($ZnZrSiO_5$).

Extracting bichromates from chromic salts. I. G. FARBENIND., A.-G. Ger. 661,175, May 19, 1938 (Sept. 17, 1932); IV*b*/12*m*. 8. Monochromates are added to aqueous solutions of chromic salts in amounts excessive of those needed for the union of the acid residue of the chromic salts with the base of the monochromates, and this mixture is subjected to usual pressure oxidation, whereupon the reaction product is worked up to the bichromate. D.A.B.

Production of iron compounds. PETER FIREMAN (Magnetic Pigment Co.). U. S. 2,127,907, Aug. 23, 1938 (March 20, 1937). The method of preparing a hydrated oxide of iron suitable for pigments comprises immersing metallic iron in a solution of an iron salt, heating and maintaining the temperature of the solution at approximately 90° to 95°C, and simultaneously supplying a gas containing free oxygen to the solution.

Production of a reactive alumina which is readily soluble in acids. T. GOLDSCHMIDT, A.-G. Ger. 660,560, May 5, 1938 (May 15, 1933); IV*b*/12*m*. 6. A monobasic aluminum sulfite of the composition $Al_2O_3 \cdot SO_2$ is heated to about 600°C. D.A.B.

Treating silicate ores. SOC. DE RECHERCHES ET D'APPLICATIONS CHIMIQUES SORAC (SOC. ANON.). Fr. 822,537, Dec. 31, 1937; *Chem. Abs.*, **32**, 4292 (1938).—Silicate ores or ores containing 1 or more amphoteric metal oxides, such as oxides of Zr, Ti, Al, Fe, or Cr, are calcined in the presence of such an amount of a Ba compound that the SiO_2 of the ore is transformed to dibarium silicate (I) and one or more of the oxides are transformed to the corresponding Ba salt, while avoiding fluxes and such an excess of Ba compound which would cause the metals to melt at the temperatures required for the formation of I.

General

Americans are leaders in ceramics. ROSS C. PURDY. *Bull. Amer. Ceram. Soc.*, **17** [9] 382–83 (1938).

Artificial lighting of vitreous enamel plant. H. H. LONG. *Foundry Trade Jour.*, **57**, 10–11 (1937). H.E.S.

Better packing, less damage. G. A. VAN BRUNT. *Factory Management & Maintenance*, **96** [7] 73–75 (1938).—G. gives hints for packing products to stand rough handling in shipment. 9 photographs. J.L.G.

Chemical observations on silicosis. J. B. ROBERTSON, F. W. SIMSON, AND A. S. STRACHAN. *S. African Jour. Med. Sci.*, **2**, 124–35 (1937); *Chem. Abs.*, **32**, 5955 (1938).—The mineral residues from the lungs in 10 cases of silicosis showed a considerable percentage of sericitic material. In both slowly and rapidly produced silicosis there was always a ratio of 2 to 1 between the quartz and the sericite present in the mineral residues. It is suggested that the rate of development and extent of the lung lesions depend on the amount of dust inhaled and the rapidity of its concentration in the lung tissue. About 10 times as much SiO_2 is dissolved from quartz as from mica in saline solutions isotonic with blood serum and of similar p_H; proteins reduce the solubility. These experiments suggest that if solubility to minute mineral particles is an essential factor in the production of silicosis, then silica rather than a silicate such as muscovite is the chief mineral concerned.

Chemist at work. R. I. GRADY AND J. W. CHITTUM. **X, Duties of a ceramist in research and plant control.** H. FRAHME. *Jour. Chem. Education*, **15** [5] 229–31 (1938).—F. describes the products manufactured by the General Ceramics Co. and gives in detail some research and plant problems in connection with the manufacture of stoneware. For Parts **V** and **XIX** see *Ceram. Abs.*, **17** [10] 326 (1938). P.G.H.

Concept of density, the physical magnitudes related thereto, and their applications to ceramics. HENRY CASSAN. *Chaleur & Ind.*, **18**, 511–16 (1937); *Chem. Abs.*, **32**, 6017 (1938).—Methods of density determination are outlined and discussed, especially volumenometric methods for porous solids for which nomograms are given. See *Ceram. Abs.*, **17** [6] 224 (1938).

Factors which determine the diagnosis of silicosis. CHARLES L. SUTHERLAND. *Brit. Jour. Radiol.*, **11**, 414–21 (June, 1938).—S. interprets the radiological factors which today characterize the diagnosis of silicosis. His descriptions, discriminations, and evaluation of these factors are elucidated by 10 large-size radiographic reproductions. K.R.

Inter-Society Color Council. DEANE B. JUDD. *Bull. Amer. Ceram. Soc.*, **17** [9] 379–81 (1938).

Part of my experience in the pottery business and my father's experience. WILLIAM J. GORDY. *Bull. Amer. Ceram. Soc.*, **17** [9] 373–74 (1938).

Practical import for silicosis problems of the Third Ordinance, increasing accident insurance in occupational diseases. LOCHTKEMPER. *Zentr. Gewerbehyg. & Unfallverhüt.*, **25**, 9–12 (Jan., 1938).—The Third Ordinance of the Third Reich represents a decided advance in industrial hygiene and the promotion of social safety and expresses the scientific theory and the practical experience of clinicians and industrial hygienists in the field of occupational injuries. This latest regulation improves on the previous Ordinances in not limiting severe silicosis to any given occupational groups but admitting claims for severe silicosis in any occupation insured by the proper association and recognized as having a dangerous dust risk, irrespective of whether such occupation was previously and expressly named as having such silicosis risk. Special emphasis is placed on protective measures for workers in dusty trades. In spite of the advance shown in the first two Ordinances, 1929 and 1936, with reference to industrial safety, the majority of plants still neglected dust hazards, did not remove danger sources of respiratory injuries, and did not recognize the hazard. Fundamental reorganization of work processes is now more successfully called to the attention of plant managements, greater mechanization of processes has ensued, and more effective dust control regulations are being used. Transfer to safer working conditions was necessary for those already jeopardized by atmospheres heavy with death-dealing dusts, and workers were brought in from other areas; these imported workers were often kept unacquainted with the danger, and when they began to show signs of disability, it became a pressing problem to determine whether they were affected before or since employment in this work. By preëmployment examinations, radiological and clinical, as well as by examinations at stated intervals after being hired, these difficulties were eliminated. Com-

pany doctors became a necessity, as they had long been to the Industrial Insurance Associations. As a result of such stringent precautions, severe silicosis has not been observed for some time, except in workers still on their jobs, though permanently impaired from the early days of disregarded hazards, and in the heavy disease losses among long-time employees. L. adds, however, "But this is not saying that silicosis possibilities have been entirely side stepped." Intensive observations are favored by the Third Ordinance on the desirability of substituting safer materials for those inevitably dangerous, *e.g.*, in the siliceous sandblasting processes and in siliceous clays and rocks. L. illustrates, from his long experience with the chamotte (fireclay) industries and the silica-crushing mills, the prolonged and expensive toll from silicosis. The definite promulgation of increased safeguards as imperative in certain industries awakened a disinclination to work therein on the part of workers who heard about the risks. Plant managements were approached, grievances were listened to, and apprehensions quieted so far as economic conditions current permitted. Too high percentages of silica in the workshop dusts, however, still prevail; in the clay pipe or tube industries, clay of widely varying silica content is utilized; research has shown that quartz ranging from 24 to 37% is relatively safe. On the average, in most readily fired clays, the quartz content is still around 40% with the probability strong that even under the Third Ordinance more silicosis will develop in the fireclay industries. Some of the pathological research problems are still unsolved, such as the exact chemical behavior of silica particles in the lung; whenever tuberculosis and silicosis appear in the same lung, the following questions arise: (1) which preceded the other, and (2) are they concurrent or merely coincident? Surprisingly, the outcome greatly hinges on these queries when they are practically involved in claims for injury. L. considers that the Third Ordinance provides more equitably than was expected for the silicosis-tuberculosis complexities. Earlier, only severe silicosis could be compensated, an accompanying tuberculosis not figuring greatly in allotment decisions but none the less plaguing complainants and adjusters. At present, the total disease condition must be severe and the probability must be shown that the silicosis has activated the characteristic course of the tuberculosis. Though experienced adjusters anticipate future problems from the wording of the Third Ordinance, L. believes that the present wording will overcome many social hardships hitherto without recourse and that adjusters of experience and breadth of view will be able to balance the factors involved. Certain Röntgen pictures may come to represent standard conditions in both diseases for comparison and for judgment, thus clarifying the situation. K.R.

Radiographic studies of the excretions of dusts from the lungs. A. E. Barclay, K. J. Franklin, and R. G. Macbeth. *Brit. Jour. Radiol.*, **11**, 405–13 (June, 1938).—X-ray examination of the chest today calls for a maximum detailed knowledge of the anatomy of the lungs and has itself been the means by which much of our present knowledge has been derived. The air-passages of the living subject can be studied and visualized by the use of opaque media. The bronchial tree is lined with ciliated epithelium. With a view to the extension of knowledge of ciliary action, the authors undertook a series of experiments designed to show by radiographs the effect of ciliary action on radio-opaque particles of bismuth carbonate and powdery lead glass. The physiological mechanisms available for the excretion of inhaled dusts are (1) the normal respiratory action of air intake and outgo, (2) coughing, and (3) the ciliary action of the bronchi, by far the most important single and normal excretory mechanism. Cats were their chief experimental animals, but preliminary tests were made upon sheep and dogs as well. The procedure is detailed and certain of the results are exhibited in 6 large-size radiographs, with comments. Healthy cats proved capable of excreting very large quantities of dry dust in a short time; these dusts in no case penetrated the alveoli of the lungs, even following 60 insufflations, unless some morbid lung or bronchial condition was already present. The acidity of substances inhaled had no appreciable effect on ciliary action in the living animal. Experiments with fluids entering the bronchioles show that they travel straight to the alveoli, bearing along any dust, organic or inorganic, which happens to be present; the ciliary action was rendered ineffective by the fluids, the normal defences against dry dusts being overcome at the same time. No radiological evidence was given to show that the dusts in these fluids passed into the lymph nodes during their slow excretion which lasts several weeks. K.R.

Radiological demonstration of pathological changes induced by certain industrial processes. J. F. Brailsford. *Brit. Jour. Radiol.*, **11**, 393–400 (1938).—B. sets forth significant changes, revealed only by radiographs, which represent insidious undermining of the health of workers. He endorses the Dept. of Industrial Hygiene recently set up at Birmingham University, with clinics at two hospitals under competent charge. Workers absorbing fluorine have been studied by Flemming Møller, a Copenhagen radiologist, who recorded in 1932, an unusual sclerosis of the skeleton, with signs of fluorine intoxication. Recently Raj Roholm published details of a clinical as well as experimental study of cryolite, the double fluoride of sodium and aluminum (Na_3AlF_6) containing 54% fluorine; it is a soft material from which volumes of fine powder are discharged at all stages of its preparation and during its use in manufacturing. The active fluorine compounds produce acute poisoning. Roholm examined 68 workers, 47 men and 21 women, 83% of whom exhibited bone changes which are described in detail as they appeared in radiographs. The preliminary symptoms are gastric and are characterized by 3 stages. The degree of osteosclerosis depended on the duration of the employment; some remarkably resistant cases are also referred to. In 34 workers pulmonary fibrosis was observed, rather like the silicosis of porcelain workers but more innocent in nature. Post mortems of two workers showed a high fluorine content in the lungs, but whether this or the associated quartz had produced the fibrosis could not be determined. Experimentally Roholm produced deleterious effects on the teeth but thought that the caries shown in high percentage in other Copenhagen workers was about the same as in the fluorine workers. Fluorine intoxication has been thought to be radiologically the same as Paget's disease, but B. examined the radiographs of a series of 154 cases, finding none of the features described by Møller and no evidence of fluorine intoxication. He reports in detail upon radiographic appearances involved, yet points out several air-borne dusts, including the silica nodule, which are difficult to distinguish. In some lungs studded with dense miliary nodules, the so-called typical nodular appearance of silicosis was in reality due to calcified miliary metastases of melanotic sarcoma. Practically all the radiographs exhibited were those of workers dying of dust inhalation, the dusts ranging from asbestos dust to dusts having a high silica content taken in by sandblast workers and those using scouring powders and including mingled dusts menacing to welders. K.R.

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